OFFICIAL
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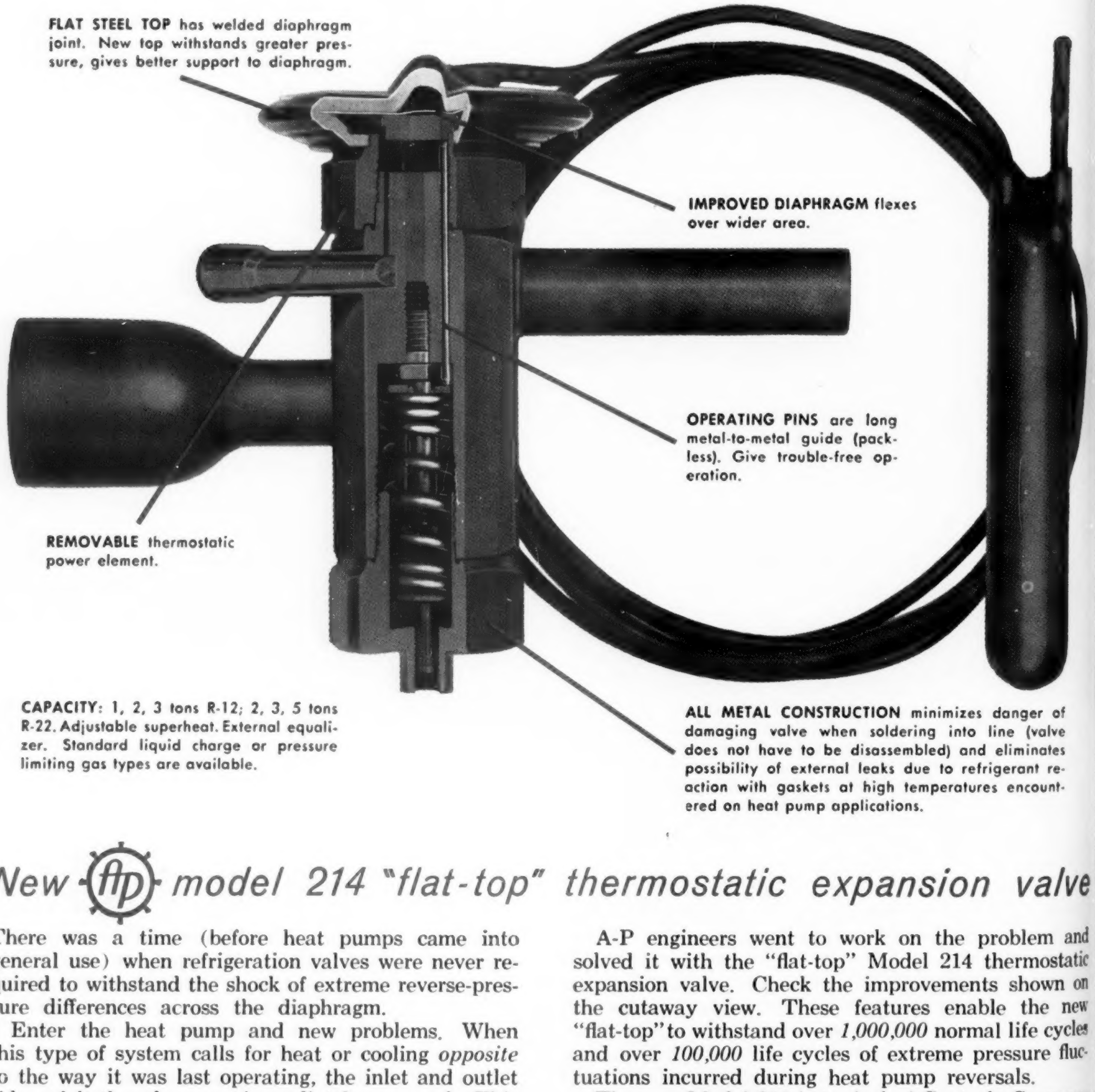
ASHRAE JOURNAL

Heating • Refrigerating • Air Conditioning • Ventilating

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS

SEPTEMBER 1959

Withstands over 100,000 life cycles of extreme pressure fluctuations in heat/cooling changeover



New (ap) model 214 "flat-top" thermostatic expansion valve

There was a time (before heat pumps came into general use) when refrigeration valves were never required to withstand the shock of extreme reverse-pressure differences across the diaphragm.

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A-P engineers went to work on the problem and solved it with the "flat-top" Model 214 thermostatic expansion valve. Check the improvements shown on the cutaway view. These features enable the new "flat-top" to withstand over *1,000,000* normal life cycles and over *100,000* life cycles of extreme pressure fluctuations incurred during heat pump reversals.

The new Model 214 is typical of Controls Company of America's ability to keep pace with the industry. It's part of industry's most complete line of refrigeration and air conditioning controls. Write today for bulletin containing complete details.

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Comment

IRRITANT OR SOPORIFIC?

It was Charles A. Dana, long-time Editor of the once-important New York Sun, who stated that after many years in the newspaper business he had found only one topic upon which he could take a firm and unequivocal editorial stand without fear of reader reprisals and that was to come out forthrightly against maneating tigers.

Every editor has that feeling at times.

We think Bernard Shaw had one answer when he wrote "In this world . . . nobody will trouble themselves about anything that does not trouble them. The attention given to criticism is in direct proportion to its indigestibility."

Not that we would follow that precept too closely, however. For we think that it is also the function of the reasonably voluble observer to inspire as well as to alarm; ever, as it were, to comment as the occasion warrants.

That one who comments does not always persuade is less important than that he induces or stimulates thought; that he provokes intelligent reactions.

At least, it becomes a goal of sorts.

MEASURES OF ACCOMPLISHMENT

For those letters we receive from member-readers with observations upon the contents of the JOURNAL, its value to them or its inherent potential for further improvement—we are always grateful.

Engineers are not given to the habit of written letter-writing of this sort. Thus, we are that much more appreciative of the courtesy when they do.

How long has it been since we heard from you? How can the ASHRAE JOURNAL serve you better? This is the seventh issue. Do you like it? Would you anticipate certain content not now carried?

Speak up, fellows.

Edward R Searles
Editor

Late news highlights

"Engineer" Beginning with the September issue, Engineers Joint Council is publishing "Engineer," a newsletter report on EJC activities, national affairs and events which affect the engineer. In addition, national legislative ,administrative and legal events of importance to the engineer will be covered. To be published monthly, copies are available without charge to individual members of the engineering societies and to a selective list of persons and organizations in industry, government and education from Engineers Joint Council, 29 West 39th Street, New York 18, N. Y.

Industrial building meeting Sponsored by a group of 28 architects and industrial executives with responsibilities for top management, construction and plant operation, the first Industrial Building Exposition and Congress will be held in New York December 12-15, 1960. The congress will consider such subjects as planning new construction, financing, modernization of older buildings, and new types of construction. Heating and air conditioning equipment will comprise one of the major categories of exhibits. To be held annually after 1960, the event is expected to attract a worldwide audience.

Trailers tested A program of pre-testing the cooling capacity of refrigerated trucks, which could lead to better quality frozen meats, fruits and vegetables, has been undertaken by the Truck Trailer Manufacturers Association. A truck's ability to maintain constant temperature and humidity levels is tested in a climate room at the Budd Co. in Philadelphia which can be heated to 110 F or cooled to −30 F. Testing equipment measures the amount of heat transferred from the room to the trailer.

Western Show Ten special clinics, sessions and seminars have been scheduled for the 3rd Western Air Conditioning, Heating, Ventilating and Refrigeration Exhibit and Conference, to be held April 27-30, 1960, in Los Angeles, according to Arthur J. Hess, first vice-president. Serving 13 western states, including Alaska and Hawaii, the event is expected to attract 20% more attendance than the previous show held in 1958.

Central systems Installed cost of central station air conditioning systems which went into operation in large multi-room buildings and commercial and industrial applications in the United States during 1958 is estimated at $550,730,000 by the Air-Conditioning and Refrigerating Systems Section of the Air-Conditioning and Refrigeration Institute. Although this figure is about 8% below the estimate for 1957 ($598,900,000), it is ahead of all other previous years.

Curriculum changes Academic reorganization of the Ohio State University College of Engineering, approved by the university's Board of Trustees on July 10, includes establishment of a Pre-Engineering Division for the first two years of pre-professional study and a Professional Division for the last three years of the five-year program. Graduation requirements are based on successful completion of the work of the Professional Division.

Insulation information An Insulation Information Center established by the National Insulation Manufacturers Association is to provide consultation services on insulation characteristics, application techniques and specifications. NIMA, 441 Lexington Ave., New York 17, N. Y.

Semiconductors Broader technical standards and marketing data for semiconductor devices are announced by the National Electrical Manufacturer's Association and the Electronic Industries Association. This joint activity is conducted through the Joint Electron Device Engineering Council, as financed jointly by Nema and EIA. Nema activities will include rectifiers and controlled rectifiers; those of EIA, diodes and transistors. Power transistors fall within the activities of each.

Overseas facts Published monthly by an inter-government body set up within the Organization for European Economic Cooperation to promote advancement of management education, spread of the latest technical skills and management techniques and generally to facilitate exchange of information, is "European Technical Digests." Copies are available from European Productivity Agency, 3 Rue Andre-Pascal, Paris-XVI, France, at a yearly subscription rate of $12.00.

Foodstuff storage General advice, limited to the handling only of produce of best initial quality, is presented in "Recommended conditions for cold storage of perishable foodstuffs," a publication of International Institute of Refrigeration, 177, Boulevard Malesherbes, Paris-17, France.

Russian Abstracts of approximately 100 Soviet technical periodicals are being made by U. S. Government agencies and released to the public as part of a program of collection and dissemination of translated technical literature. They are listed in "English Abstracts of Russian Technical Journals," a free publication of the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

Gas-fired heaters There were 29.1% more gas-fired central heating units shipped during the first half of this year than in the same period of 1958, as reported by the Gas Appliance Manufacturers Association.

Exchange visits U. S. National Academy of Sciences and the Academy of Sciences of USSR have signed a two-year agreement providing for exchange visits by research scientists of each country for periods up to one year. Each Academy will designate 20 fields of specialized inquiry.

Fact control Methods for keeping pace with the vast production of building science information published currently throughout the world and of making the new knowledge more conveniently available will be considered at the Fall conference of the Building Research Institute to be held in Washington, D. C., November 17-19.

Responsibility Syracuse University has announced a Liberal Education Seminar on "Public Responsibility" for scientists and engineers from the northeastern United States. The three major topics of the program, which will be held September 13-19 at the University's Sagamore Center in the Adirondacks, are: economic growth, citizen action in local communities and international relations. Dr. Alan B. Knox, Administrator, Adirondack Centers, University College, 610 E. Fayette St., Syracuse 3, N. Y., is in charge of arrangements.

Irradiation Dealing with research and development in the field of radiation preservation of food, and listing all reports on this process, is a "Catalog of Technical Reports", CTR-357 "Food Preservation by Irradiation, 1951-58", which has just been issued. Copies are available from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., for 10 cents.

Success Recipient Wayne E. Springer of the 1958 Homer Addams-ASHVE Award has completed his graduate student work in environmental studies at the University of Illinois and received his M.S. degree in Mechanical Engineering. He goes this fall to the Boeing Aircraft Company for projects allied with environmental physiology as applied to the design and development of accommodations within the cockpits of aircraft and in manned space vehicles.

Pursuant to advice of Counsel, the official and correct name of ASHRAE is identified as American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. It is further advised that this precise designation should be used by officers, directors, regional directors, chairmen of committees, etc., for purposes of exactness and uniformity; especially for all documents of a legal nature or legal implication.

OFFICIAL PUBLICATION ASHRAE JOURNAL
SEPTEMBER 1959

Design requirements for

Industrial air systems

JOHN H. CLARKE
Member ASHRAE

Plant ventilation and air conditioning today are no longer a luxury but important, and in some cases, essential utilities for production. The principal reasons for this are:

Increased automation and more efficient design and operation of our plants have resulted in greatly increased production and annual product value. Where our systems can protect or appreciably increase this valuable production they are good investments.

The demand for efficiency has been evidenced in many cases by huge, integrated, single story plants having high internal heat loads. Air conditioning and mechanical ventilation are important to such buildings in order to maintain a desirable environment for the workers and, frequently, for the product.

In recent years there has been a greater concern for the safety and comfort of the workers. This has paid good dividends in increased production.

As a plant utility industrial systems provide many services, among them are make-up air and control of the space conditions such as temperature, humidity, air movement and, in conjunction with the exhaust systems, air-borne contaminants. The benefits of these installations are reflected in improved product quality and production, improved worker efficiencies and reduced employee sickness and absenteeism. Reduced boiler load resulting from heat recovery or conservation may be an auxiliary benefit of a well-designed system. Each system should be applied to as many tasks as practical in order to increase the return on the investment.

DESIGN REQUIREMENTS

Building and process requirements – The design of a good industrial ventilation or air conditioning system begins with the preliminary design of the plant, process and building. These should be such as to permit efficient, practical ventilation. Large glass or monitor areas should be eliminated or minimized, hot equipment shielded or insulated and heat and humidity loads reduced, where feasible, by changes in design or process. Exhaust hoods should be carefully designed to reduce their make-up air requirements to the minimum.

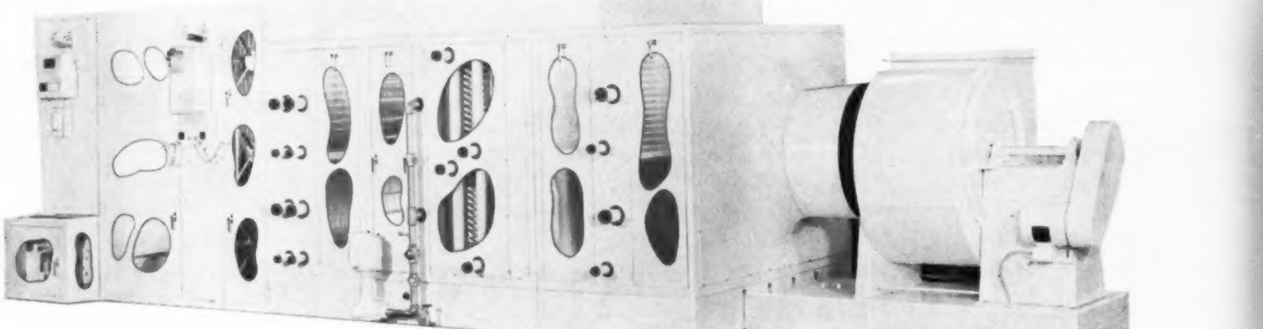
Ventilation duct work requires considerable space and must compete for that space with piping, conduit, controls, production and other equipment, the building structure, and working spaces. Also, means must be provided for support of the ducts and outlets. In craneway areas it may be necessary to provide space for branch duct drops behind the crane rails.

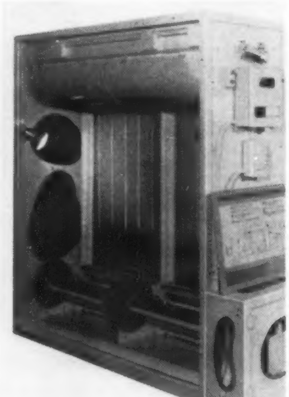
Additionally, a location with accessibility for maintenance must be found for the equipment. Fan and equipment rooms in the building are always preferable. Where the building structure permits, a good location appears to be the roof, in penthouses, especially when a number of fans and equipment can be serviced at the same time. Truss platforms have been used successfully but are most effective where a number of units are located there and interconnected by catwalks which are accessible, in turn, by stairs. One company at least is providing building "lean-to's" at ground level for its large 60,000 to 100,000 cfm systems. This is an excellent location and yet the equipment is out of the main plant areas.

In recent years there has been

Ventilation and air supply are essential to industry whether for heating or cooling, for both or for fuller air conditioning there are many practical factors to be considered. Significant improvements are being made with relief ventilation systems using either outside air directly or evaporatively cooled air. In still other cases large volumes of make-up air for process and fume exhaust provide safety and improved working conditions.

John H. Clarke is Engineering Supervisor, Viking Corp., Div. of Union Carbide Corp. His paper at the Industrial Ventilation Conference, ASHRAE annual meeting, Lake Placid, N. Y., June 22-24, 1959, appears herewith in slightly abridged form.

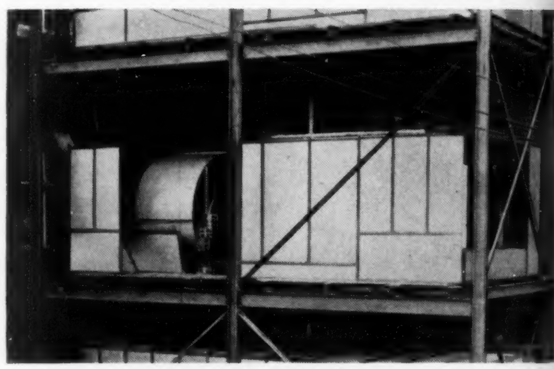




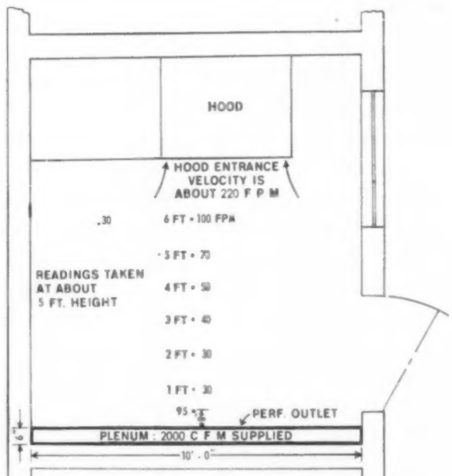
A

B

Prefabricated supply system may consist of a filter, preheater, washer, reheater, bypass sections and fan. This is of 25,000 cfm capacity. (A) Fan end. (B) Filter end

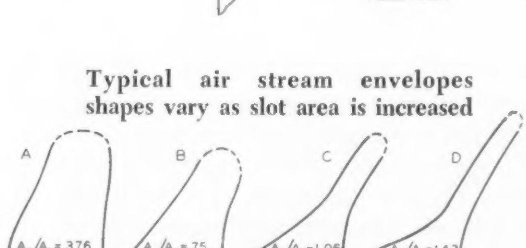


Panel type prefabrication of system casings permits full flexibility as to components and assembly or reassembly on the job

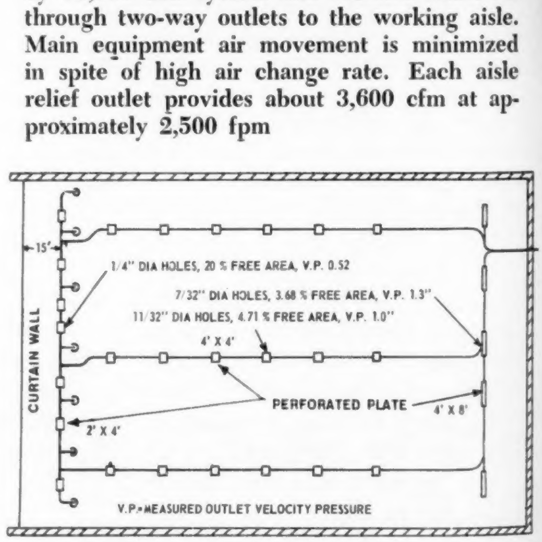


Small laboratory, 10 x 11 ft 4 in. and 10 ft 3 in. high is supplied 2,000 cfm of make-up air through a 10 x 8 ft perforated wall panel. Air change rate is 35 sec. Panel velocity is 25 fpm. Perforations 3/16 in. diam. Free area 2.76%

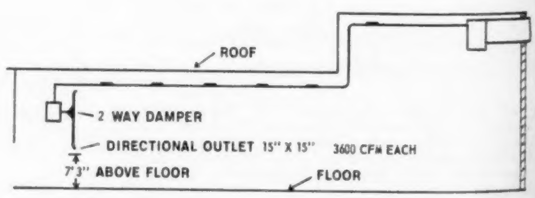
Typical air stream envelopes shapes vary as slot area is increased

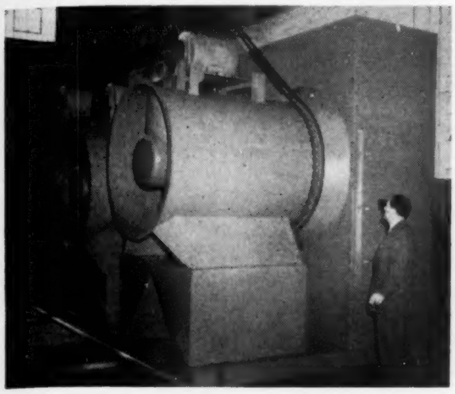


Chemical process area supplied with make-up by 75,000 cfm system also receives relief air through two-way outlets to the working aisle. Main equipment air movement is minimized in spite of high air change rate. Each aisle relief outlet provides about 3,600 cfm at approximately 2,500 fpm



140' × 90' 12,600 SQ. FT. VOL. 346,000 CU FT GROSS





A

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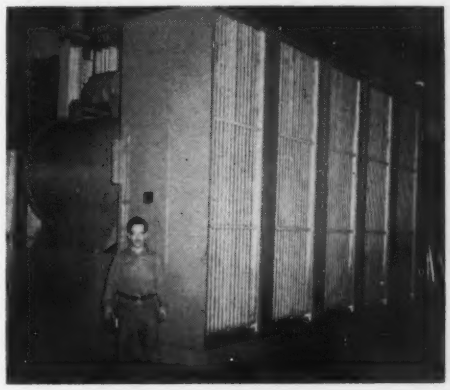
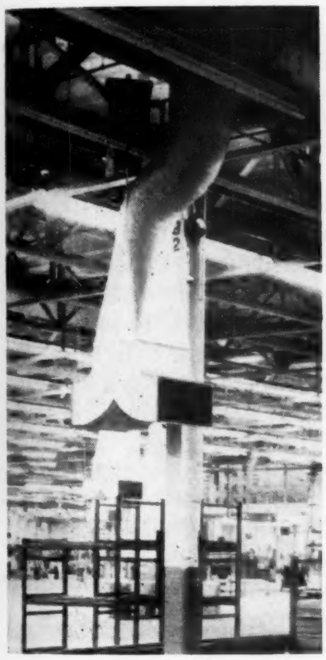
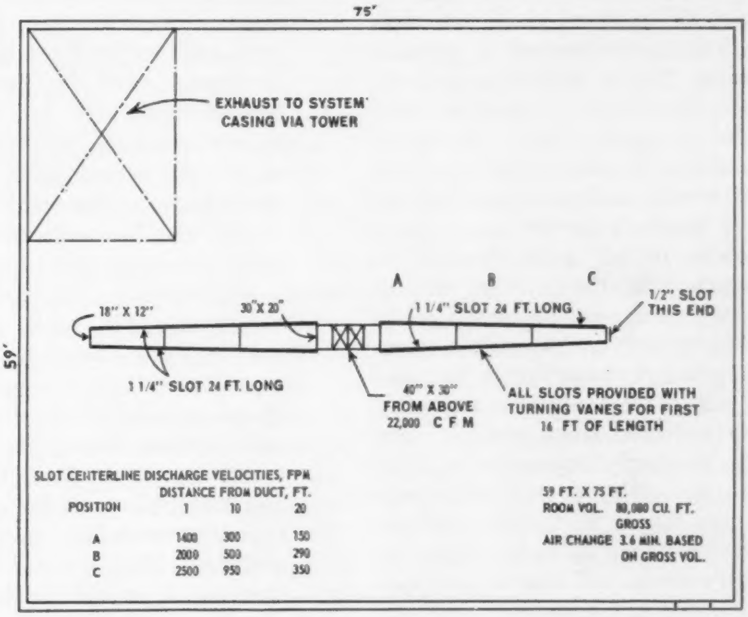


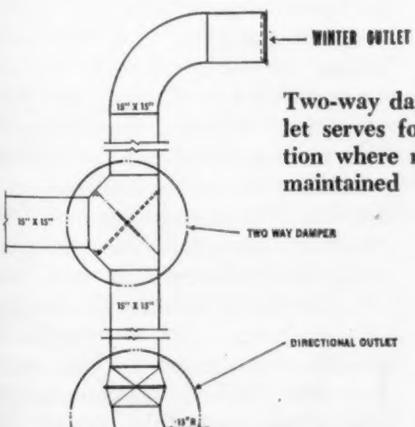
Prefabricated make-up air units resemble package types but allow relative freedom in selection of components. This unit has a capacity of 140,000 cfm. (A) Fan end. (B) Heater end; note vertical installation of heater



Outlet drops at the building columns and the use of directional grilles preserves space

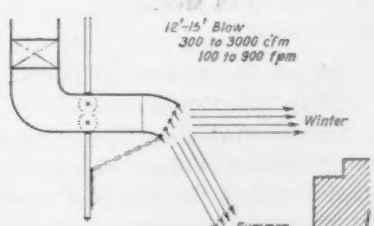
This arrangement of slot outlets on both sides of a supply duct maintains a chemical process area at constant temperature. It features a high air change at considerable air movement but assures high capacity in small space

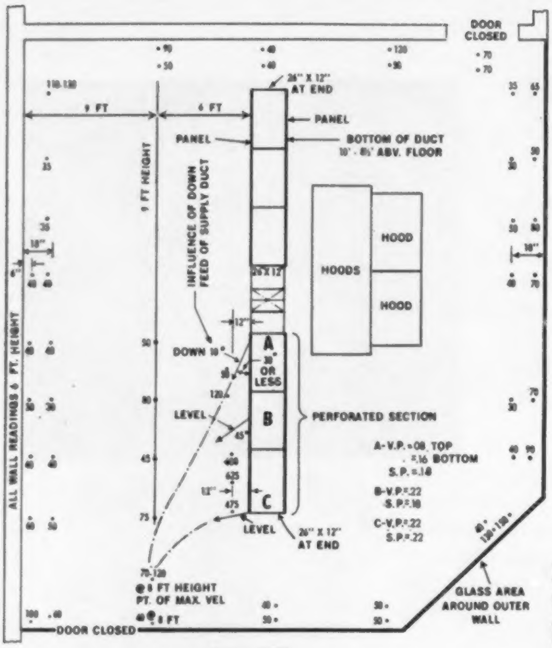




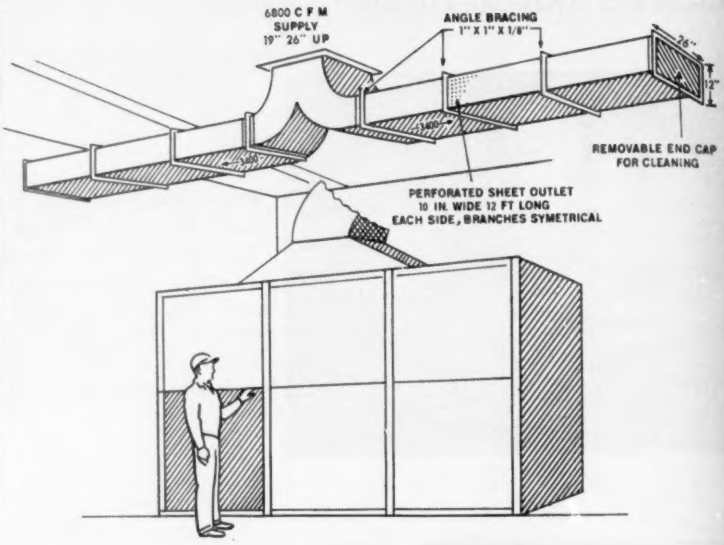
Two-way damper and directional outlet serves for aisleway relief ventilation where make-up volume must be maintained

Directional louvers, gang operated from the floor by a chain, serve well for metals fabricating areas and for seasonal factors. In winter heat recovery is provided by mixing supply air with the hot air rising from the equipment





PLAN VIEW



How a 8,900 cfm duct, perforated panel, make-up and heating system distributes the air. Supply is through four 10 x 12 ft perforated panels in the duct sides. Room air change rate is 2.2 min

an unfortunate trend toward hanging units, mostly of the package type, 15 to 30 ft above the floor with no access except by portable ladder. This is definitely poor design. The major problem in plants today is maintenance. Excessive handicaps simply make the problem worse. In lieu of portable ladders safety rules of most plants require rolling scaffolds with an attendant at the bottom. Equipment power must be turned off by an electrician or responsible operator, plant personnel must be roped off and plant equipment and product protected from possible damage. A simple inspection or oiling of a ceiling-hung unit under such circumstances is tedious and expensive. And in most cases, the units simply will not be serviced.

System casings and components – Design requirements of the system casings and components need thorough study, and could well be the subject of a paper for a future symposium. Essentially, the design and installation should accomplish the following:

Locate the system for accessibility and maintenance.

Locate the inlets to minimize the intake of dust and fumes, and reduce the effects of wind pressure on system capacity and building balance.

Provide adequate space in each system casing compartment for inspection, cleaning, repair and uniform air flow; similarly, space must be provided around equipment.

Provide good temperature control. This means that objectionable, wasteful overheating should also be controlled.

Provide freeze protection by careful selection, design and installation of the inlets, dampers, heaters, controls, fans, piping and piping accessories. Thorough mixing of return air and uniform flow to the heaters is essential. Stratification and localized impingement on the heater tubes must be avoided. Good condensate drainage from the air heaters must be assured.

Use of package and prefabricated air handling equipment – Over the years most manufacturers of air handling equipment have developed various types of package equipment designed to save space and cost. It would appear that this equipment is designed as competitive, rather than quality equipment. It has been greatly oversold by vendors who are anxious to make a sale, by engineers who want to save design and drafting time, and by architects who prefer to wall up the equipment, stuff it in a corner or hang it up in the air —anything to get it out of the way.

Obviously, the vendor must sell equipment. However, a greater effort should be made to sell quality equipment where it is needed. Owners and engineers must also recognize the need. Savings on first cost and space are important; but if package equipment is purchased on this basis alone it is the wrong approach. Quality, reliability and low maintenance costs are even more important factors.

These package units are too compact to permit proper inspection and maintenance of the filters, heaters, cooling coils and fans. Frequently, side panels must be removed for access, making the problem more difficult. The slide-in filter arrangements, where used, are poor, discourage replacement and prevent good filtering. Lack of space in the units, and their usual shape, prevent selection of the components for efficiency and good operation. Vertical installation of the air heater tubes is considered a prime prerequisite for freeze protection. The fan arrangements and the long horizontal heaters on many units are inefficient and cause serious stratification, control and freezing problems. Air distribution is greatly complicated by the multi-fan units. Volume measurement is difficult or impossible. Service life is comparatively short. The alleged lower cost of these package

units is frequently an illusion. Because of the design and maintenance problems, they seldom maintain their related capacities.

If these comments are carefully considered, if proper maintenance is provided, and if these units are applied to jobs for which they are well suited, they will provide acceptable service. The package units are best applied for ordinary ventilation or make-up systems requiring little or no duct work. They should be located on the floor or on an accessible roof. For the latter location, all components including dampers, heaters, controls and traps should be accessible from the roof.

Roof supply air fan units, with short duct extensions to the outlets, are popular for effective, economical, supplementary summer relief ventilation. Properly installed on accessible roof areas, they give excellent service and are easy to maintain.

There is seldom a case of white or black for these problems. But for ventilation and air conditioning systems which are important or essential to plant production or safety, the package units should not be used. There are alternates. It is possible, even in this day and age to design built-up systems. This takes time, but with experience the details can be standardized and the time kept to a minimum. If the sheet metal contractors wish to expand their business they can hire an engineer to develop standard designs, and fabricated panels and shapes to be used on incremental sized units. There is a real need to standardize system sizes and this should not be difficult to do. At least three equipment manufacturers are making prefabricated ventilation systems. For these, the designer can select the components for efficiency and the job to be done. Equipment sections are then made up, shipped to the customer and, where the size requires it, bolted together on the job site. These systems approach, and in some cases, excel the quality of the individually designed built-up systems.

To design industrial supply air systems properly engineers must be informed on the physiological requirements for bodily heat removal by convection and sweat evaporation. Goals of Effective Temperature or Heat Stress Index must be established for the specific working conditions. Desirable air movement varies considerably with the job, the season and the worker. Directionalizing or volume control of the supply air is extremely important except in fully air conditioned spaces.

Desirable air motion at the worker will vary from 50 to 100 fpm for fully air conditioned or partially cooled supply systems. A maximum of 200 fpm has been established for continuous exposure at fixed working positions. (Ref. 2) At spot cooling locations, velocities as high as 4000 fpm have been used for intermittent exposure. These are maximum velocities and the worker should be provided with the means to reduce them as desired.

AIR DISTRIBUTION

Little or no supply duct work is required for ordinary make-up supply systems unless they also provide heat relief, or unless the resulting air motion would be unacceptable to the worker or process. At high air change rates it may be possible to supplement the primary air with air from adjoining spaces. This is often done in process or laboratory areas. Where low air motion and high air change rates are required, distribution duct work and perforated plate outlets are frequently necessary.

Air conditioned spaces, or spaces provided with general relief ventilation, require extensive duct distribution to control the space conditions. Horizontal runs at low level may be provided where it is possible to hang the duct work. But lack of supports has dictated the use of building columns for many outlet locations. Spot cooling requires much less duct work because relief is provided at the work stations only. No attempt is made to provide relief for the general building area.

Supply air quantities required for air conditioning can generally be determined within acceptable limits. There is no easy solution for determining the volumes required for relief ventilation. Capacities based on temperature rise, air change or cfm per sq ft are valueless except where substantiated by experience and similar installations. As is the case for dilution systems, the air required is relatively independent of the building volume.

It is the workers' environmental conditions that are important for relief systems. The keystone of adequate relief, for heating or cooling, is that the supply air must be delivered to the work zones In this way the work zones can be maintained within a few degrees of the supply air temperature, and air motion can provide additional relief.

OUTLET TYPES AND THEIR USES

A supply air jet in a free space acts as a pump and will entrain large quantities of air. As a result the outlet jets will slow down and approach ambient temperature rapidly. Consequently, for general relief ventilation the outlets should be located low, not more than 10 ft above floor level, to discharge the air to the work zone without mixing with warm ceiling air. For spot cooling the outlets should be large – 12 to 30 in. size – and must be brought as close as is practical to the worker to take advantage of the large, relatively cool core of air at the outlet.

Outlets vary considerably in their characteristics. Nozzles or grilles of low aspect ratio (nearly square) have long throw (blow length) and high entrainment. Long slots have relatively shorter throw and high entrainment. Circular diffusers have short throw and high entrainment for a flat pattern. Perforated panel outlets have short throw and low entrainment. The characteristics of the outlet should be fitted to the job. Other important factors are as follows:

Generally the outlets should be provided with directional or volume control from the floor by means of rope, chain or pole.

Heat relief is often necessary at outside temperatures well below acceptable supply air temperature. Consequently, provision for tempering the air is highly desirable to extend the use of the system.

(*Continued on page 96*)

Performance characteristics of a

Water-jacketed vortex tube

Vortex tubes are usually constructed as shown in Fig. 1, and act to divide the compressed supply air into two air streams issuing from the hot and cold tubes at temperatures which are respectively higher and lower than that of the supply air. The hot air stream is not of high enough temperature to cause consideration of the vortex tube as a heating device, but the temperature of the cold air stream is sufficiently low to provide a refrigeration source. Therefore, the vortex tube is ordinarily evaluated as a refrigerator, and it has been demonstrated that its coefficient of performance is significantly lower than that of other refrigerators.

The coefficient of performance of a refrigerating system is expressed as the ratio of the refrigerating effect produced by the system to the energy which must be put into the system to obtain that effect. With the vortex tube the refrigerating effect is a function of the temperature and the mass rate of flow of the cold air stream, and the energy supplied to the system is that required to compress the supply air. The divided flow tube is thus seen to be at a disadvantage efficiency-wise because of the necessity for compressing more air than is available for refrigeration. The air which leaves through the hot tube absorbs energy in compression but makes no direct contribution toward the refrigerating capacity of the system. The entire function of the hot air stream is to prevent violation of the First Law of Thermodynamics by carrying away the energy removed from the cold air stream. Vortex tubes which cool all of the air entering the nozzle might be expected to have a higher coefficient of performance than split flow tubes.

F. E. HEFFNER

In order to test this mode of operation a 1.50-in. diameter vortex tube with a water-jacketed, closed-end, variable-length hot tube was constructed and tested. This tube was tested operating both from nozzle pressures above atmospheric to atmospheric, and from atmospheric nozzle pressure into a vacuum system. These jacketed tube studies were made at the conclusion of an engineering investigation of the design of a conventional counterflow tube, and the physical dimensions of the jacketed tube were the same as those of the conventional tube. Data from the conventional tube tests are presented herein as a basis of comparison for the jacketed tube.

Description—The internal arrangement of the tubes tested was basically as shown in Fig. 1. The nozzles were located so that their centerlines were tangent to the inside diameter of the hot tube and the centerpiece was shaped properly to direct the air issuing from the nozzle smoothly into its spiral path within the hot tube.

Fig. 2 shows the components used in the jacketed tube tests. Item 1 is the water-jacketed hot tube. It was 1.50-in. inside diameter with the water jacket starting near the nozzle and extending 47 in. The cooling water entered at the nozzle end. The three sizes of nozzles which were tested are shown as item 2 and the centerpiece and cold tube are shown as item 3. The centerpiece was made from a plastics-impregnated duck and the cold tube from reinforced plastics tubing with a ½-in. wall thickness. These materials were selected to provide thermal insulation and thereby exclude extraneous heat losses or gains. The

A vortex tube which substitutes another means of energy removal for the hot air stream and which thereby cools all of the air entering the nozzle might be expected to have a higher coefficient of performance than the usual split flow tube provided that the mechanism of energy redistribution which takes place within the hot tube is not disordered by the change. The author has investigated one other means of examining the performance characteristics of a water-jacketed vortex tube. Here are the results of his investigation.

F. E. Heffner is a Senior Research Engineer in the Research Laboratories of the General Motors Corp. The material in this paper has been abstracted from the author's M.Sc. thesis, "The Vortex Tube", Wayne State University, 1951.

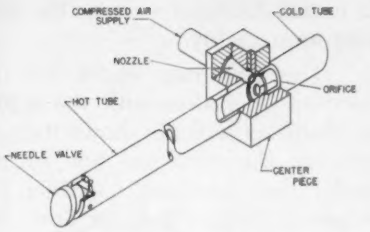
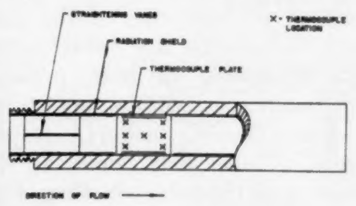


Fig. 1 Vortex tube

Fig. 3 Cold air temperature tube



piston (4) and hose assembly (5) were used to close the hot tube during the pressure tests and allowed its length to be varied during the tests. The hose was attached to a gauge to indicate the static pressure at the axis of the hot tube. The piston was not used during vacuum tests, the hot tube being sealed at its end by a rubber stopper.

The test instrumentation was conventional and does not require detailed description. Flow rates were measured with sharp-edged orifice meters built according to the ASME standards or by calibrated flow nozzles. The entering air temperature was always near ambient and was measured by thermocouples in the supply lines where velocity effects were negligible.

The cold air temperature was measured in the tube shown in Fig. 3 which replaced the cold tube of Fig. 2. The cold air entered the tube from the left with the rotational velocity it had as it passed through the orifice. The function of the straightening vanes was to induce mixing of the air to eliminate temperature gradients produced by the vortex action. The air then passed over the copper thermocouple plate and its mean temperature was determined from readings of the thermocouples located as shown. The ½-in.-thick tubing provided insulation against conduction heat losses and the polished brass radiation shield eliminated radiation losses.

Quantitative performance parameters for the vortex tubes were

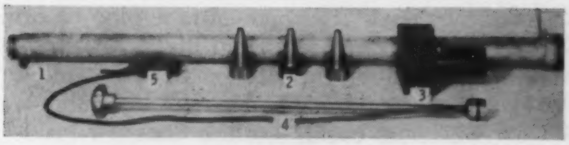
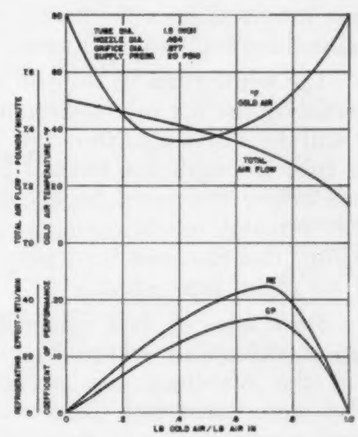


Fig. 2 Jacketed vortex tube

Fig. 4 Vortex tube constant supply pressure characteristics – 1.50-in. tube



calculated as though the tubes were part of an arbitrary refrigerating cycle which consisted of an adiabatic air compressor, a constant pressure cooler, the vortex tube expander, and a constant pressure heater. Here the refrigerating effect in this cycle is the product of the mass rate of flow of the cold air, its specific heat, and the difference between the cold air and inlet temperatures. The work of compression is the adiabatic work required to compress all of the air entering the nozzle. The coefficient of performance is the ratio of these two quantities. The following equations express these relationships.

Refrigerating effect

$$RE = w_c c_p (T_i - T_c) \qquad \text{Btu/min.}$$

Work of compression:

$$W = w_i c_p T_i \left[(P_i/P_c)^{(k-1)/k} - 1 \right] \qquad \text{Btu/min.}$$

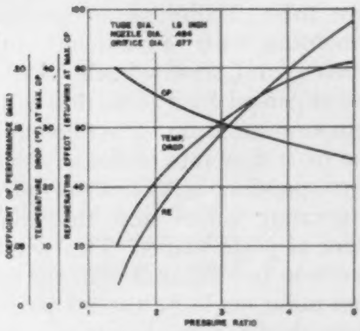
Coefficient of performance:

$$COP = \frac{\alpha (1 - T_c/T_i)}{(P_i/P_c)^{(k-1)/k} - 1}$$

where:

- c_p = specific heat of air at constant pressure
- k = specific heat ratio of air
- w_c; w_i = mass rate of flow of cold air and inlet air, respectively
- P_c; P_i = abs. pressure of cold air and inlet air, respectively
- T_c; T_i = abs. temp. of cold air and inlet air, respectively
- α = cold air fraction = w_c/w_i

Fig. 5 Vortex tube optimum performance characteristics – 1.50-in. tube



It should be noted that the refrigeration cycle postulated for the performance calculations tends to give high refrigerating effects and coefficients of performance. Calculation of the refrigerating effect from the cold air temperature up to the inlet temperature gives a maximum cooling capacity. The adiabatic work of compression is a minimum estimate of this input work; and the result of both of these effects is to give an optimistic performance coefficient. This method of calculation does, however, provide a basis for comparing the various designs of the vortex tube, and it will be seen that it applies equally well to both the pressure and vacuum operation.

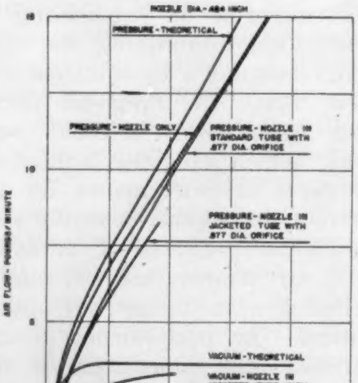
Performance – Tests on the jacketed vortex tubes were conducted subsequent to an engineering investigation establishing the optimum design of a conventional split flow tube. The optimum nozzle and orifice sizes selected were those which gave the highest coefficients of performance for the tube. Other nozzle or orifice sizes might be preferred if minimum cold air temperature or another criterion were selected for optimization. The performance characteristics and dimensions of this optimum split flow tube are given in Figs. 4 and 5. Fig. 4 is a typical set of constant pressure characteristics with the performance shown

as a function of the cold air fraction. Fig. 5 shows the performance of the tube as a function of the pressure ratio when the cold air fraction is set for maximum coefficient of performance at each pressure ratio.

The experiments on the jacketed, closed-hot-tube, vortex tube were influenced by a phenomenon which did not occur in the split flow tube. Under some operating conditions, the closed-end tube emits a loud, shrill whistle which is accompanied by a reduction in the temperature drop, a reduction in the mass flow rate of the air, and a corresponding reduction in the refrigerating effect and the coefficient of performance. This whistle is not to be confused with the normal noise made by the air passing through the tube; but it is a definite, high-pitched sound superimposed on this normal noise. The whistle can be produced in split flow tubes with hot tubes of sufficient length if the valve restricting the hot flow exit is completely closed. It was noted, however, that the slightest opening of this valve would stop the shrill noise.

The cause of the whistle was not established, but the following empirical observations were made. The sound is not caused by the air moving through the orifice, because it persists when the orifice plate is removed. It is not a function of the diameter or length of the cold tube, and it persists when the cold tube is removed. It cannot be stopped by placing a short

Fig. 6 Vortex tube flow characteristics



re-entrant pipe of orifice diameter from the orifice plate into the hot tube; but it can be stopped by placing a long, thin-walled tube of orifice diameter inside and concentric with the hot tube if this inner tube ends several inches from the orifice plate. Although this form of inner tube arrangement stops the whistle, it reduces the performance of the vortex tube to about the same extent as does the sound, so that nothing is gained by its use.

The whistle can be stopped by shortening the hot tube sufficiently as will be discussed later; but as the tube is lengthened beyond the point where the sound begins, the pitch remains nearly constant, indicating that the noise is not caused by an organ pipe effect.

Since none of these minor design modifications served to prevent the whistling, the jacketed tubes were tested with the conventional construction; and the resulting data are presented with suitable notations to indicate whether the tube was whistling or not.

The mass flow rate through the vortex tube influences the refrigerating effect and the coefficient of performance, and the relationship between the pressure ratio and the flow rate varies considerably with different modes of operation. A summary of these effects is presented in Fig. 6. The curves, marked "Pressure — Theoretical" and "Vacuum — Theoretical," were calculated from the St. Venant and Wantzel nozzle equation.

The rate of flow through the standard tube is about the same as that through the nozzle alone, but closing the hot tube increases the hot tube pressure so that the nozzle and orifice act as two series restrictions in the air path and reduce the flow accordingly. The mass rate of flow with vacuum operation is less at a constant pressure ratio than that for the pressure operation as would be expected.

The effect of orifice size on flow rate is shown in Fig. 7A with the jacketed, full-length hot tube for both pressure and vacuum operation. It can be seen that the nozzle and orifice are functioning as a pair of restrictions and that increasing the resistance of the second restriction through a reduction in orifice diameter reduces the flow rate appreciably.

The flow rate curve for the vacuum operation with the 0.500-in. diameter orifice is shown dashed, because the tube did not whistle under this operating condition. A relatively higher rate of flow was obtained under this non-whistling operation.

The temperature drop, the refrigerating effect, and the coefficient of performance of the jacketed, full-length hot tube, vortex tube operating at both pressure and vacuum conditions are shown in Figs. 7B, 7C, and 7D, respectively. These data were all obtained with the tube whistling. Figs. 7D and 5 permit a comparison of the coefficients of performance of split flow and jacketed tubes with 0.484-in. nozzles and 0.877-in. orifices. The figures show that the split flow operation gave a coefficient of performance of .18 at a pressure ratio of two while the coefficient of performance of the jacketed tube was only .12 during whistling operation.

In comparing the performance of the jacketed and split flow tubes, it is necessary to consider the effect of the cooling water temperature on the jacketed tube performance. In order to obtain comparable operation of the two types of tubes, the flow rate of the water in the cooling jacket was so regulated that the water leaving the jacket was at the same temperature as the air entering the nozzle. In general, the flow rate of the water was great enough so that its temperature rise was small and the jacket water remained nearly at a constant temperature equal to that of the inlet air. This scheme was adopted in an effort to avoid introduction of additional refrigerating capacity simply from the use of cold water. If colder water were used, the coefficient of performance calculation would have to be modified to take its refrigerating effect into account.

Another general observation can be made from Figs. 7B, 7C, and 7D which show that the nozzle size influences the jacketed tube pressure operation more than its vacuum operation and that larger nozzles perform better in the pressure system.

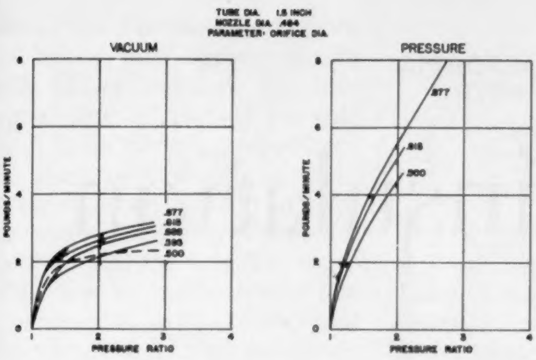


FIG. 7A

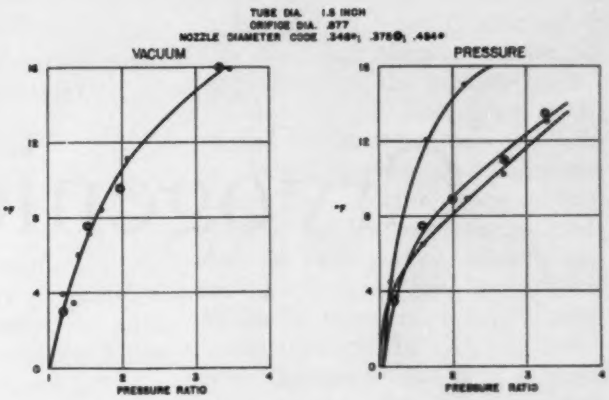


FIG. 7B

Fig. 7 Jacketed vortex tube performance (tube whistling); A – air flow; B – temperature drop; C – refrigerating effect; D – coefficient of performance; E – effect of tube proportions

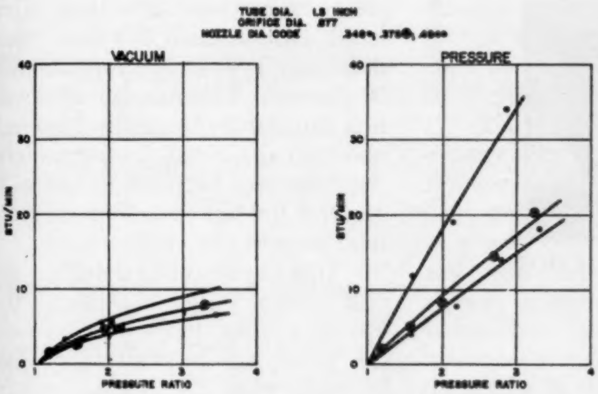


FIG. 7C

FIG. 7D

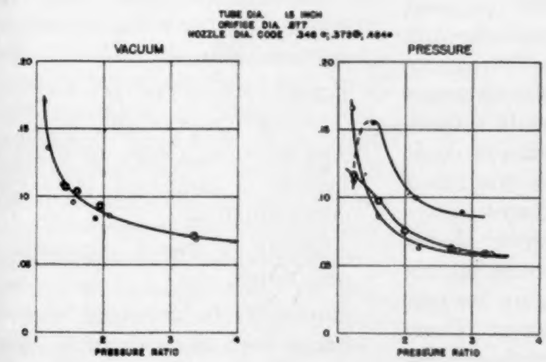
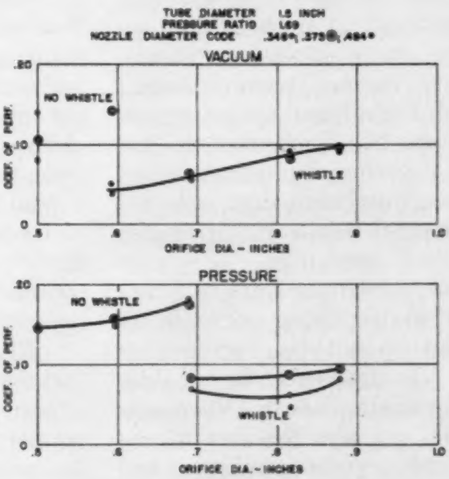


FIG. 7E



In order to determine whether an optimum combination of nozzle size and orifice size existed for the jacketed operation, a series of tests with various combinations of nozzles and orifices was run. The results of these tests are shown in Fig. 7E which gives the coefficients of performance at a constant pressure ratio. Fig. 8 is a similar plot at nearly the same pressure ratio for the optimum performing split flow tube. A comparison of these figures shows that for pressure operation at orifice diameters less than about 0.70 in., where the jacketed tube would operate without the whistle effect, the two tubes operated at nearly identical performance coefficients. The data are more erratic for vacuum operation of the jacketed tube, but the non-whistling operation here also gives performance coefficients comparable to those of the split flow tube. Again, the data indicate that the nozzle size has little effect on the jacketed tube performance during vacuum operation and small orifice pressure operation.

These preliminary tests showed a great similarity between the split flow tube operation and the jacketed tube operation except for the whistle effect. On the basis of this similarity a final series of pressure operation tests were conducted on a jacketed tube whieh had the nozzle and orifice diameters that had given the best operation in the split flow tube. This series of tests was conducted with the hot tube shortened by the piston in Fig. 2 to prevent the whistle operation.

The results of these tests are summarized in Figs. 9A and 9B. These data show that the jacketed tube gives about the same coefficient of performance at the longest allowable hot tube length as did the optimum performing split flow tube shown in Fig. 5. It should be noted that the jacketed tube data of Figs. 7B, 7C, and 7D were obtained with the tube whistling while the better performance of Figs. 9A and 9B occurred when the tube was not allowed to emit its whistle.

(*Continued on page* 71)

Cryogenic insulation

R. H. KROPSCHOT

Selection of an insulation to be used for cryogenic applications will greatly influence equipment design. The same insulation is not necessarily the best for all uses. These uses include the insulation of storage vessels, transport vessels, transfer lines, liquefiers, missiles, distillation columns and laboratory apparatus.[1] This paper discusses the various insulation techniques currently being used and provides some examples of their applications. The material is divided into five sections: (a) High vacuum insulation; (b) Multiple layer insulation; (c) Vacuum powder insulation; (d) Rigid foam insulation; and (e) Supports. Each section discusses experimental techniques of obtaining insulation data, selected experimental results and apparatus using such insulation.

The pioneering work of James Dewar[2] in developing cryogenic insulations cannot be over-emphasized. He invented the double-walled vacuum flask or Dewar vessel. He was also the first to use evacuated powder insulation and multiple layer insulation. Thus, the original ideas presented by Dewar before the turn of the century constitute the basic ideas behind present-day insulation techniques.

HIGH VACUUM INSULATION

Use of high vacuum is the most common insulation technique for cryogenic applications. This type of insulation consists of an evacuated space between two good reflecting surfaces. The heat transfer is predominately by radiation but there may be a significant contribution due to residual gas conduction.

R. H. Kropschot is with the Cryogenic Engineering Laboratory of the National Bureau of Standards. This paper was presented at the Cryogenic Conference at the ASHRAE annual meeting in Lake Placid, N. Y., June 22-24, 1959.

Radiation – The rate at which radiant energy is transferred from one surface to another is dependent upon the emissivity (e) and absorptivity (a) of the surfaces and upon the quantity ($T_1^4 - T_2^4$), where T_1 and T_2 refer to the temperatures of the hot and cold walls respectively.[3] In practice, radiation heat transfer calculations are simplified by assuming "gray" surfaces.

Experimental evidence[4] shows that the absorptivity of most metals is nearly constant for wave lengths greater than 2 to 4 micron. Thus, the assumption of "grayness" for metal surfaces at and below ambient temperature is a good approximation.

Table I gives minimum recorded values of emissivity for some selected cryogenic materials.[4,5,6] Normal e_n and hemispherical e_h emissivities have been tabulated indiscriminately since their difference is at most approximately 30 percent. This amount of deviation can usually be ignored in engineering calculation. Unfortunately, the difference between e_n and e_h is greatest for the case of most practical interest, i.e., $e << 1$.

TABLE I
EMISSIVITIES OF SELECTED MATERIALS*

Surface	Temperature R 7.6	137	540
Aluminum	.011	.018	.03
Brass	.018	—	.035
Copper	.0050	.008	.018
Gold	—	.01	.02
Silver	.0044	.008	.02
Stainless Steel	—	.048	.08
50 Pb-50 Sn Solder	—	.032	—
Most non-metals	—	—	>0.8

* A much more complete list can be found in references 4, 5, and 6.

It is important to note that the best surface is not necessarily the one that looks the best. However, the following generalizations can be made from the existing experimental data.[7]

Materials having the lowest emissivities also have the lowest electrical resistance.

Emissivity decreases with decreasing temperature.

Apparent emissivity of good reflectors is increased by surface contamination.

Alloying a metal increases its emissivity.

Emissivity is increased by treatments such as mechanical polishing which result in work hardening of the surface layer of the metal.

Visual appearance (i.e., brightness) is not a reliable criterion of reflecting power at long wave lengths.

Good reflecting surfaces and thus lower heat transport due to radiation can be obtained in several ways:

Application of annealed aluminum or copper foil.

Electroplating silver or gold to a thickness of approx 0.001 in.

Chemical deposition of silver on nonmetals and chemically inert metals such as stainless steel.

Constructing equipment from materials having low emissivities.

Residual Gas Conduction—At pressures below one micron of Hg kinetic theory predicts the heat transport due to residual gas conduction to be directly proportional to the pressure. Under these conditions the molecules collide with the walls more frequently than with each other and the Knudsen equation[8] for free molecular conduction can be used to calculate the heat transport. For long concentric cylinders the Knudsen equation takes the form

$$Q = \frac{A_1}{2}\left(\frac{\alpha_1\,\alpha_2}{\alpha_2 + \frac{r_1}{r_2}(1-\alpha_2)\,\alpha_1}\right)\frac{\gamma+1}{\gamma-1}\sqrt{\frac{R}{2\pi}}\,\frac{P}{\sqrt{TM}}\,(T_2 - T_1) \qquad (1)$$

where Q is the rate of heat transfer, A is the surface area, α is the accommodation coefficient, r is the radius of the cylinder, γ is the ratio of specific heats Cp/Cv, R is the universal gas constant, p is the pressure, T is the absolute temperature, and M is the molecular weight of the residual gas. The subscripts 1 and 2 refer to the inner and outer cylinders respectively and the temperature T without the subscript should be measured at the gage that measures the pressure p.

The accommodation coefficient α is a measure of the temperature equilibrium between the wall and the gas, i.e., $\alpha = T_i - T_e/(T_i - T_w)$ where T_i is the effective temperature of the incident molecules, T_e is the effective temperature of the reflected (or emitted) molecules, and T_w is the effective temperature of the wall.

The limited literature on accommodation coefficients has been summarized by Partington.[9] The results show that α is dependent upon the type of residual gas, the surface material and condition and the temperature. Table II lists some values of α at low temperatures derived from the data of Knudsen[10] and Keesom and Schmidt.[11]

There are many examples of how high vacuum insulation is used in Cryogenics. One such example is shown in Fig. 1. It is a 500 liter liquid hydrogen dewar developed by the National Bureau of Standards.[12] The surfaces of the dewar are especially prepared to obtain a low emissivity. In addition, a liquid nitrogen cooled radiation shield is interposed between the ambient container and the hydrogen container. The shield allows low cost liquid (N_2) to intercept most of the heat transport from ambient temperature.

TABLE II

APPROXIMATE ACCOMMODATION COEFFICIENTS

T, R	Helium	Hydrogen	Air
540	0.3	0.3	0.8-0.9
137	0.4	0.5	1
36	0.6	1	—

The use of the radiation shields, either cooled like Fig. 1 or floating isothermally will greatly reduce the heat transport from a hot surface to a cold surface. For example, if we could support several radiation shields isothermally between the warm and cold walls the heat transport will be reduced approximately as $\frac{1}{(n+1)}$ where n is the number of radiation shields. On the other hand if we support one nitrogen cooled shield between a room temperature surface and a liquid hydrogen surface we reduce the heat transport to 1/500 to 1/1000 of its original value. The remaining heat is dissipated in the liquid nitrogen by evaporation.

High vacuum insulation is used almost exclusively for the insulation of liquid hydrogen and helium transfer lines. Fig. 2 shows examples of two transfer lines currently being used. In Fig. 2a, two concentric tubes are separated by triangular teflon spacers. A Richards[13] seal-off valve is attached to the line and offers a convenient way of sealing the vacuum space.

In Fig. 2b fiber glass is attached to the inner line and held in place with perforated aluminum foil.[14] The vacuum space is then charged to 1.5 atmospheres pressure of pure carbon dioxide and sealed off from the atmosphere. When the inner line is cold (during liquid transfer) the CO_2 condenses onto the inner line and is held there by the glass wool resulting in a pressure of less than 10^{-5} mm Hg. When the line warms to ambient temperature the CO_2 pressure returns to 1.5 atmospheres thus allowing the line to be stored for extended periods with less danger of losing its insulation ability if very small leaks are present.

MULTIPLE LAYER INSULATION

In an effort to develop a technique for spacing multiple floating radiation shields we have produced a new type of insulation.[15] It consists of alternating layers of good reflectors separated by poor conductors. Many different combinations of reflector-insulator layers have been tried and the best results have been obtained with aluminum foil reflectors separated by thin glass paper. Fig. 3 shows a schematic drawing of the calorimeter used for testing these insulations. The sample to be tested is wrapped onto the test and guard chambers in a lathe and then inserted into the vacuum chamber and evacuated. The guard and test chambers are then filled with cryogenic fluid, either liquid N_2 or liquid H_2, and the rate of evaporation of liquid measured with a wet test

A new technique of separating multiple radiation shields in a high vacuum using glass paper has been investigated. The mean effective thermal conductivity between 36 and 540 R is less than 3 x 10^{-5} Btu hr^{-1} ft^{-1} R^{-1}, or about 10 times better than the best evacuated powder insulations. Use of this type of insulation is especially advantageous where pay load is very important, for example, in the transport of liquid helium.

The conductivity of a wide variety of evacuated powders is presented also. The addition of 20 wt. percent of aluminum powder to silica aerogel or perlite can reduce the effective thermal conductivity to ¼ of its original value. The use of high vacuum insulation for transfer lines and dewar vessels is discussed. Representative emissivity data are presented.

meter and timer. All of the heat entering the test chamber flows in radially and an "effective" conductivity $\bar{k}$ between ambient temperature and low temperature is computed from the relation

$$\bar{k} = \frac{Q \ln \frac{r_o}{r_i}}{2\pi l\,(T_2 - T_1)} \qquad (2)$$

where Q is rate of heat transport to the test chamber, and l, r and T are defined in Fig. 3.

Table III shows representative data taken with this apparatus. The best results (lowest apparent conductivity) were obtained using thin aluminum foil separated by Dexter glass paper made from B fibers.

TABLE III

APPARENT MEAN THERMAL CONDUCTIVITY OF SOME SELECTED MULTIPLE LAYER INSULATIONS

Insulating Material	0.008 in. D.P.[1]		0.0048 in. D.P.[2]		0.007 in. O.C.[3]		Nylon Net[4]	0.008 in. D.P.[1]
Reflecting Surface	0.00023 in. Al Foil		0.0005 in. Al Foil		0.0005 in. Al Foil		0.0005 in. Al Foil	Al Mylar[5]
d_i In.	4.0		4.0		4.0		4.0	3.1
d_o In.	6.57		7.00		6.48		6.38	6.4
# of Shields per in.	55.		47.		29.		80.	—
Approx. Sample Density lb/ft^3	7.5		7.5		6.9		5.6	3.8
Pressure Sample space mm. Hg	$<10^{-5}$		$<10^{-5}$		$<10^{-5}$		$<10^{-5}$	$<10^{-5}$
Boundary Temp. R	540 / 137	540 / 36	540 / 137	540 / 36	540 / 137	540 / 36	540 / 137	540 / 137
$k \times 10^5 \frac{\text{Btu}}{\text{hr Ft R}}$	3.5	2.3	3.0	2.4	4.1	3.0	13.2	18.6

1. 0.008 in. thick glass paper B fiber, Dexter Paper Company.
2. 0.0048 in. Dexter paper.
3. 0.007 in. thick polystyrene bonded "Fiberglas" mat, average fiber diameter 0.00070 in., Owens-Corning Fiberglas Corp.
4. Purchased from local dry goods store. Thickness 0.0065 in., 92% void.
5. 0.0005 in. Aluminized "Mylar", metallized both sides (1.5-2.0 ohm resistance per square) Dobeckmun Company.

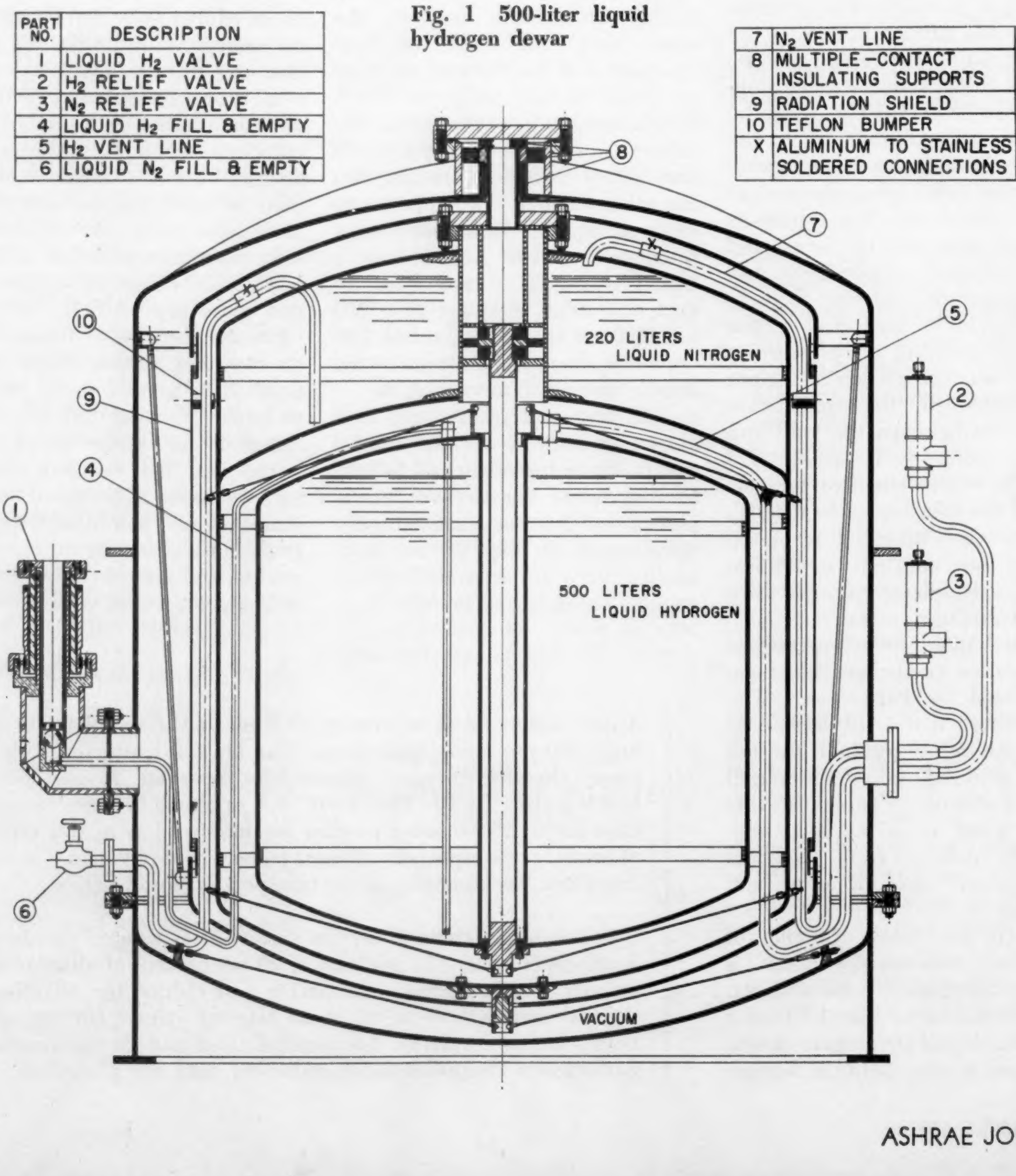


Fig. 1 500-liter liquid hydrogen dewar

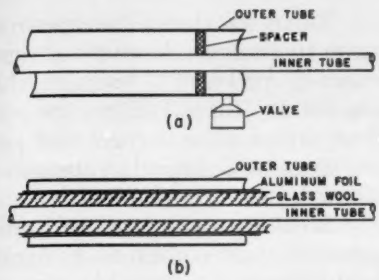


Fig. 2 Typical liquid transfer lines (a) high vacuum insulation (b) 1.5 atmospheres of carbon dioxide condenses on the inner surface when the line is in operation

These new insulations will permit the construction of large transport vessels for liquid helium (and hydrogen) which will not require nitrogen cooled radiation shields. The conductivity of the best wrapped insulations is approximately 1/10 that of the best powder insulations. Thus, for a given rate of heat transport to the inner container a much greater pay load can be carried. In addition, for certain applications this type of insulation can be used as a support for the inner container. This could permit reducing the heat transport due to supports by a significant amount. However, for stationary tanks and equipment where thick insulation can be tolerated the evacuated powder may be superior due to greater ease of installation.

We have investigated the use of multiple layer insulation for transfer lines. Although this insulation may have a much lower thermal conductivity than can be obtained with high vacuum, it also has a higher heat capacity. Thus, for the insulation of lines which have only intermittent use its applicability is questionable.

VACUUM POWDER INSULATION

Finely divided powders such as expanded perlite, silica aerogel, calcium silicate and diatomaceous earth make excellent cryogenic insulations. They are easy to install and not exceptionally expensive when compared to the cryogenic apparatus being insulated. In addition, they are about as good an insulator at a pressure of 10^{-3} mm Hg as they are at much lower (10^{-6} mm Hg) pressures thus reducing the vacuum requirement. A detailed discussion of heat transport through powder insulations has been published by Fulk.[16] This article presents extensive data and a complete bibliography.

Fig. 4 shows a schematic drawing of the calorimeter in use at the National Bureau of Standards for studying the heat transfer through powders.[17] The heat transport from the outer (warmer) surface evaporates the cryogenic liquid (nitrogen, hydrogen or helium) in the measuring vessel. The total heat transport is then computed from the relation

$$Q = L\left(\frac{dM}{dt}\right)\frac{\rho_{liq}}{\rho_{liq} - \rho_{vap}} \qquad (3)$$

where Q is the rate of heat transfer, L is the heat of vaporization,

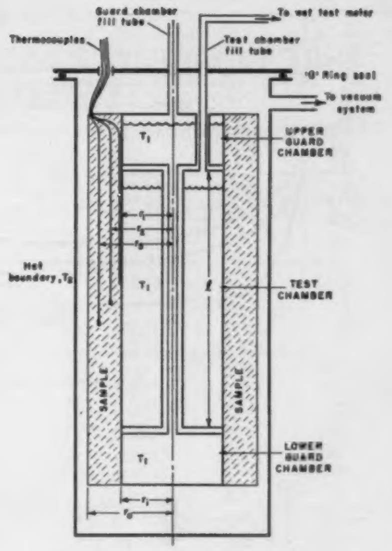


Fig. 3 Schematic drawing of a calorimeter for testing multiple layer insulations

$\frac{dM}{dt}$ is the mass rate of flow of the vapor leaving the measuring vessel and $\frac{\rho_{liq}}{\rho_{liq} - \rho_{vap}}$ corrects for the vapor that merely replaces liquid and does not leave the vessel. The guard vessel intercepts heat entering the top of the chamber due to radiation and conduction. By venting the effluent gas through a water bubbler the guard vessel is maintained at a temperature slightly higher than the measuring vessel so that the vapor from the test chamber does not recondense as it flows to the wet test meter. This

Fig. 4 Schematic drawing of a calorimeter for testing evacuated powder insulations

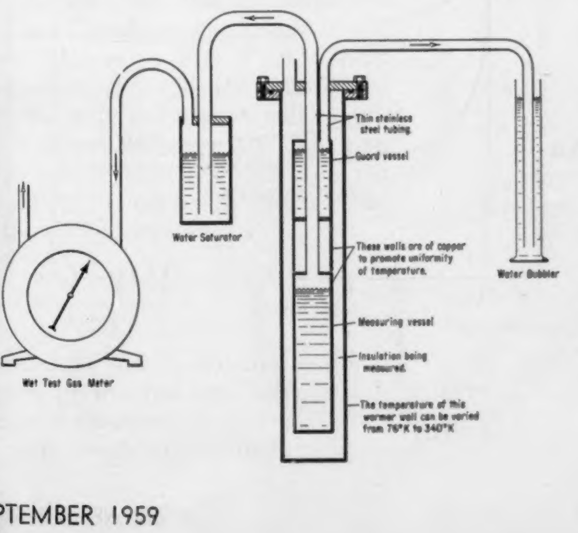
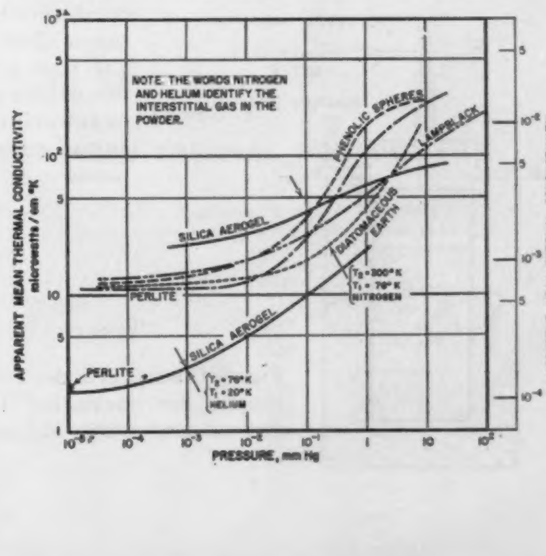


Fig. 5 Thermal conductivity of several insulating powders and the variation with interstitial gas pressure



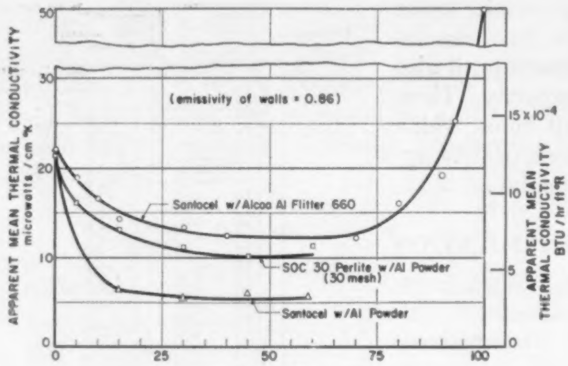


Fig. 6 The thermal conductivity between 540 and 137 R of Santocel A and perlite with added aluminum

Table IV shows the apparent mean thermal conductivity of some selected powders[16] between 137 and 540 R. Table V shows the conductivity of silica aerogel and perlite at several boundary temperatures.

Radiation through ordinary powders may constitute a significant portion of the total heat transport. This contribution can be reduced by the addition of an opacifier. Fig. 6 shows the effect of adding an aluminum powder opacifier to silica aerogel and perlite.[17] Details of this work will be published elsewhere.[18]

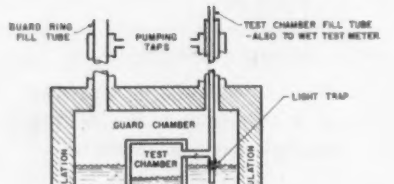
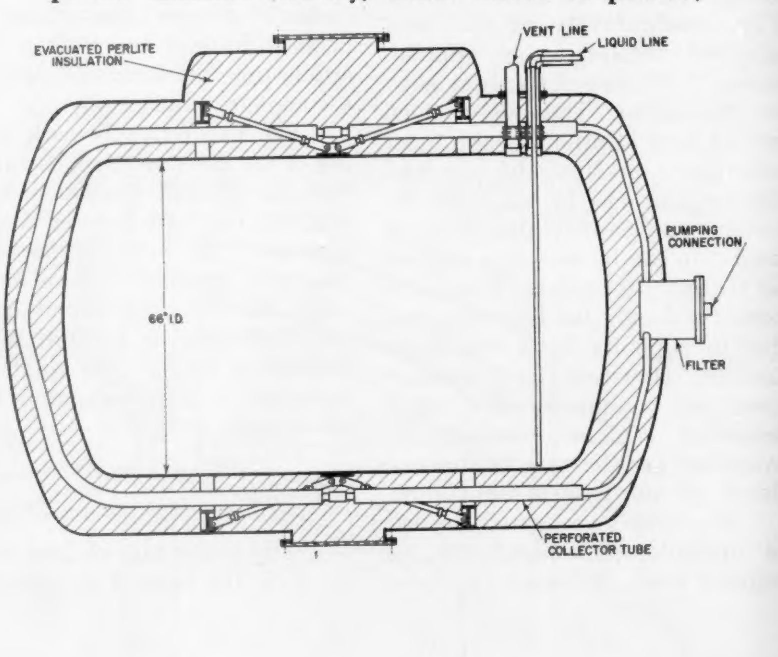


Fig. 8 Schematic drawing of a flat plate calorimeter

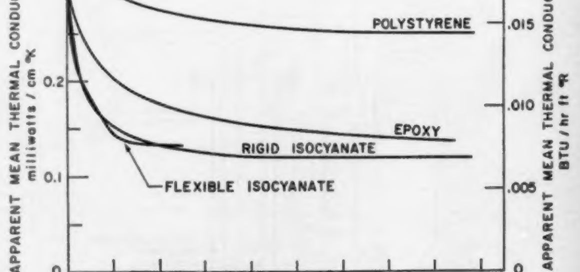
Fig. 7 Transport vessel for liquid hydrogen with evacuated powder insulation (courtesy, Beech Aircraft Corporation)



apparatus can be used to measure insulation of varying thickness by substituting outer vessels of various diameters.

The pressure dependence of the apparent mean thermal conductivity of some selected powders is shown in Fig. 5. The boundary temperatures and types of interstitial gases are labeled on the respective curves. It should be noted that at pressures below 10^{-3} mm Hg the thermal conductivity is almost constant.

Fig. 10 Apparent mean thermal conductivity between 540 and 137 R as a function of time under evacuation for some selected foams



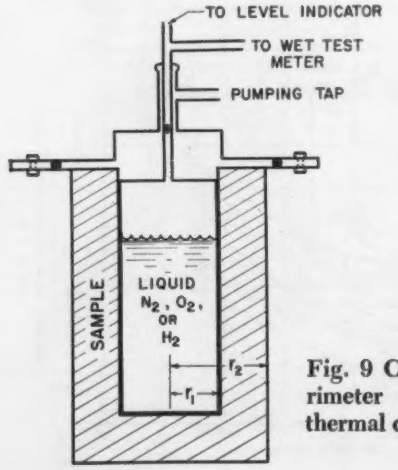


Fig. 9 Coaxial cylinder calorimeter for measuring the thermal conductivity of foams

Although the vacuum requirement on powder insulations is not as restrictive as it is for high vacuum or multiple layer insulations it nevertheless can present some problems. Most powders are hygroscopic and should therefore be dried before using, or provisions should be made to heat them during the first evacuation. Electrical or steam heating of the vessel can often be used. Another valuable technique is to admit hot dry air at a point opposite the pumping line so that the dry gas must travel through the moist powder.

The gas being evacuated from the powder usually has to travel a quite tortuous path. Therefore, multiple pumping taps or channels should be installed in any container utilizing much powder. In addition, these pumping taps should be filtered to keep the finely divided powder from entering the vacuum pump.

An example of a large transport vessel for liquid hydrogen using vacuum powder insulation is shown in Fig. 7.[10] It has an actual capacity of 6,000 liters and a rated capacity of 5,400 liters. Its evaporation rate is approximately 1.5 percent of the rated capacity in 24 hr.

RIGID FOAM INSULATION

Foam as used throughout this paper defines a class of materials having cellular structure. Foams can be made of polystyrene, polyurethane (isocyanate), rubber, glass, silica and other materials. These materials are used extensively for refrigeration applications but have limited use in cryogenics because of their relatively high thermal conductivity.

The thermal conductivity of foams can be readily measured with a flat plate calorimeter of the type shown in Fig. 8. The heat transport through the sample of thickness X and area A will evaporate liquid from the test chamber. The rate of heat flow Q is obtained from Eq. 3 and the apparent mean thermal conductivity is

$$\bar{k} = \frac{QX}{A\,(T_2 - T_1)} \qquad (4)$$

where T_2 and T_1 are the temperatures of the hot and cold boundaries respectively.

A simple apparatus for obtaining the approximate thermal conductivity of foams is shown in Fig. 9. A heavy copper container is inserted into the center of the foam block and the entire sample is enclosed in an external container. The copper container is then filled with cryogenic fluid and the evaporation rate is measured. The accuracy of this measurement is relatively poor (± 10 to 20 percent) but may be entirely adequate for many applications. (If the foam is of the closed cell type the copper container is usually not required.)

Table VI shows some representative data on the apparent mean thermal conductivity of foams between 540 and 137 R. In general, the thermal conductivity of all foams will be determined by the gas contained in the individual cells plus a contribution due to solid conduction. The conductivity for polystyrene is approximately 50 percent higher than a similar curve for air.[7] Likewise the polyurethane foam has approximately twice the conductivity of carbon dioxide. The polyurethane (isocyanates) were blown with carbon dioxide and measured almost immediately.

When the test space of the calorimeter Fig. 8 is evacuated the thermal conductivity of the foam samples decreases. Fig. 10 shows the effect of evacuation on conductivity of some selected foams between boundary temperatures of 540 and 137 R. These results estab-

TABLE IV

APPARENT MEAN THERMAL CONDUCTIVITIES OF SOME EVACUATED POWDERS

(1.0 in. thickness between walls 540 to 137 R and having emissivity greater than 0.8)

Powder	Remarks	Gas Pressure (mm Hg)	ρ (#/ft³)	k (10^{-4} Btu hr^{-1} ft^{-1} R^{-1})
Silica Aerogel:	Chemically prepared, 250A	$<10^{-4}$	6.	12
		N_2 at 628	6.	113
		He at 628	6.	358
		H_2 at 628	6.	462
	+10% free silicon dust—by weight	$<10^{-4}$	7.	10.5
Silica:	Flame prepared, 150-200A	$<10^{-4}$	3.7	12
	N_2 at 630		3.7	107
Perlite:	expanded, +30 mesh	$<10^{-4}$	3.7	12
	+30 mesh	$<10^{-5}$	6.	10.5
	+30 mesh	N_2 at 628	6.	193
	+30 mesh	He at 628	6.	735
	+30 mesh	H_2 at 628	6.	845
	—30 +80 mesh	$<10^{-4}$	8.0	7
	—30 +80 mesh	N_2 at 628	8.0	188
	—30 +80 mesh	He at 628	8.0	730
	—30 +80 mesh	H_2 at 628	8.0	840
	—80 mesh	$<10^{-4}$	8.7	5.8
	—80 mesh	N_2 at 628	8.7	202
	—80 mesh	He at 628	0.14	780
	—80 mesh	H_2 at 628	0.14	840
	—30 mesh	$<10^{-4}$	0.14	2.8
Calcium Silicate:	(synthetic), 0.02μ	$<10^{-5}$	11	3.2
	0.02 to 0.7μ	$<10^{-4}$	22	4.3
	0.02 to 0.07μ	N_2 at 628	22	262

TABLE V

APPARENT MEAN THERMAL CONDUCTIVITY

Evacuated silica Aerogel and Perlite powder with several boundary temperatures
(1.0 in. thickness between walls having emissivity greater than 0.8)

Powder	(Remarks)	Boundary Temp. R T_2	T_1	Gas Pressure (mm Hg)	ρ #/ft³	$\bar{k}$ (10^{-4} Btu hr^{-1} ft^{-1} R^{-1})
Silica Aerogel	(Chemically prepared)	540	137	$<10^{-5}$	6	12
		137	36	$<10^{-5}$	6	1.2
	250 A					
Perlite	(expanded)	540	137	$<10^{-5}$	8.7	5.8
		540	36	$<10^{-5}$	8.7	3.8
	(—30 mesh)	137	36	$<10^{-5}$	8.7	1.2
		137	7.6	$<10^{-5}$	8.7	0.46

TABLE VI

APPARENT MEAN THERMAL CONDUCTIVITY OF SOME SELECTED FOAMS

Foam Type	Density lb/ft³	Boundary Temp R	Test Space Pressure	$\bar{k}$ Btu / hr ft R	Supplier and Trade Name
	2.4	540-137	1 Atm	1.9×10^{-2}	Dow Chemical Co.
Polystyrene	2.9	540-137	1 Atm	1.5×10^{-2}	"Styrofoam"
	2.9	137- 36	10^{-5}mm Hg	0.47×10^{-2}	
	5.0	540-137	1 Atm	1.9×10^{-2}	Debell & Richardson
Epoxy Resin	5.0	540-137	10^{-2}mm Hg	0.97×10^{-2}	"Du Ra Foam"
	5.0	540-137	4×10^{-3}mm Hg	0.75×10^{-2}	
Polyurethane		540-137	1 Atm	1.9×10^{-2}	Nopco Chemical Co.
(isocyanate)	5.0-8.5	540-137	10^{-3}mm Hg	0.7×10^{-2}	"Lock Foam"
Rubber	5.0	540-137	1 Atm	2.1×10^{-2}	U. S. Rubber
Silica	10	540-137	1 Atm	3.2×10^{-2}	Pittsburgh Corning "Foam Sil"
Glass	9	540-137	1 Atm	2.0×10^{-2}	Pittsburgh Corning "Foam Glass"

lish fairly conclusively that gas conduction constitutes a significant portion of the thermal conductivity of foam insulations.

SUPPORTS

Heat enters a cryogenic vessel by two main paths: (1) through the insulation and (2) through the support members. Recent developments have perfected insulations to such an excellence that the heat entering through the supports can constitute over 50 percent of the total.[20] Thus, new methods of reducing heat transport due to support members are of prime importance. Techniques of providing long thermal paths have been investigated.[12,21] In addition, the use of some new materials having high design stress and low thermal conductivities have also been studied. Table VII shows a comparison of some selected support materials. Column one is the recommended design stress σ_y for these materials.[22] The yield strength (0.002 offset) was used for the metals. Column two is the average thermal conductivity $\bar{k}$ between 540 and 36 R, except as noted. Column three is the ratio σ_y/k. A high value of this ratio is desirable for good support members. Since stainless steel is often used for a support material, column four shows the ratio σ_y/k divided by σ_y/k for annealed stainless steel type 304. When compared in this manner the non-metallic materials appear very good for supports. Arnett[23] has used Dacron webbing to support the inner container of a 50 gal liquid oxygen container with complete success.

Appreciation is extended to Mr. M. M. Fulk and Dr. R. J. Corruccini for many helpful discussions during the preparation of this paper. In addition, J. E. Schrodt and B. J. Hunter were of assistance in taking and compiling data.

TABLE VII

COMPARISON OF MATERIALS

Used for support members (σ_y is the design stress and $\bar{k}$ is the average thermal conductivity between 36 and 540 R.)

Material	σ_y ksi	$\bar{k}$ Btu hr^{-1} ft^{-1} R^{-1}	$\sigma_y/\bar{k}$	F[4]
Aluminum 2024	55	47	1.17	.20
Aluminum 7075	70	50	1.4	.24
Copper annealed	12	274	.044	.007
Hastelloy[1] "B"	65	5.4	12	2.0
Hastelloy[1] "C"	48	5.9	8.1	1.4
"K" Monel[2]	100	9.9	10.1	1.7
Stainless Steel 304 (ann)	35	5.9	5.9	1
Stainless Steel (Drawn 210 ksi)	150	5.2	29	4.9
Titanium pure	85	21	4.0	.68
Titanium alloy 4A1-4Mn	145	3.5	41.4	7.0
Dacron[3]	20	0.088*	227	38.5
Mylar[3]	10	0.088*	113	19.1
Nylon	20	0.18	111	18.8
Teflon[3]	2	.14	14.3	2.4

* Room Temperature value
[1] Haynes Stellite Co.
[2] International Nickel Co.
[3] E. I. duPont
[4] $\sigma_y/\bar{k}$ divided by $\sigma_y/\bar{k}$ for stainless steel

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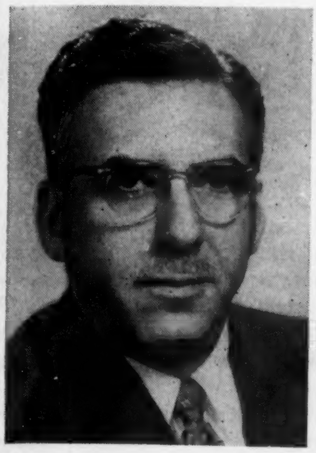
D. D. WILE
Guest Sponsor

Regional Operations



D. D. WILE
First
Vice
President
ASHRAE

Long prior to the merger of ASHAE and ASRE, both Societies had organized Chapters into Regions and delegated various responsibilities to the regional organizations. This had become necessary to insure proper representation of the Chapters without requiring a governing body of unwieldy size. The regional setup of ASHRAE combines the best features of both of the former Societies. There are ten Regions.

The Regional Director—Of key importance to the regional system is the Regional Director. He is a member of the Board of Directors of the Society, is nominated by the Nominating Committee of the Society and elected to serve for a period of three years by ballot of the Society membership. He is responsible for the following duties:

1. Keep in close touch with the Chapters and branches in his Region by necessary visits and correspondence. Advise them of ways of improving their operations.
2. Represent the Chapters of the Region on the Board of Directors and the Regions Central Committee.
3. Serve as Chairman of the Chapters Regional Committee and help to organize the activities of that committee (see following).

The Chapters Regional Committee—Close coordination between Chapters and the national organization would be a difficult matter if it were not for the Chapters Regional Committee. This important group meets at least once each year at a convenient location within the Region and is attended by a delegate and alternate from each Chapter of the Region together with one or more Society officers and the Staff Secretary in Charge of Membership. Any other Society member may attend. The meeting usually occupies a full day and is a most important line of communication between the Chapters and the national organization. This committee performs these functions:

1. Selects a member and alternate member to serve on the National Nominating Committee of the Society.
2. Receives recommendations for improvement of any phase of Society operation. These recommendations are known as "Chapter agenda items" and are referred, through the Regions Central Committee, to appropriate committees or individuals for consideration.
3. Receives reports on the welfare and progress of the Chapters and holds discussions on methods of improving Chapter operation.

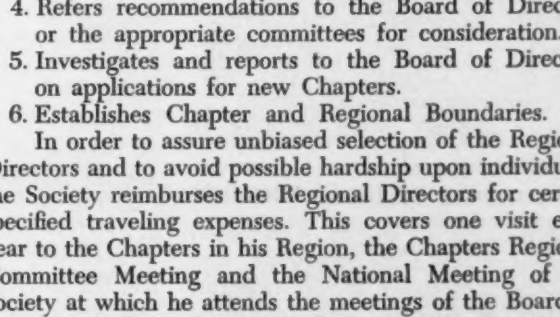
Regional Meetings—The Chapters Regional Committee meetings are sometimes combined with a "Regional Meeting" which may extend over several days and feature technical sessions and social events similar to National Meetings. These Regional Meetings can be highly effective in bringing the benefits of the Society to many who might not ordinarily have the opportunity to attend National Meetings.

The Regions Central Committee—This is composed of the Regional Directors and the Second Vice President of the Society who is its chairman (By-Laws Sec. 8.8.6) and who also coordinates the activities of the Regional Directors throughout the year. The committee activities are:

1. Meets twice each year during the Annual and Semi-annual Meetings.
2. Receives reports on the welfare and progress of the Regions and holds discussions on methods of improving Region and Chapter operation.
3. Acts as a clearinghouse for recommendations from the Chapters, especially for "Chapter agenda items" referred to it from the Chapters Regional Committees.
4. Refers recommendations to the Board of Directors or the appropriate committees for consideration.
5. Investigates and reports to the Board of Directors on applications for new Chapters.
6. Establishes Chapter and Regional Boundaries.

In order to assure unbiased selection of the Regional Directors and to avoid possible hardship upon individuals, the Society reimburses the Regional Directors for certain specified traveling expenses. This covers one visit each year to the Chapters in his Region, the Chapters Regional Committee Meeting and the National Meeting of the Society at which he attends the meetings of the Board of Directors and Regions Central Committee. For similar reasons, the Society also reimburses traveling expenses of the delegates and alternates to the Chapters Regional Committee Meetings.

Regional organization of our Society has played an important part in the handling of the recent merger at the Chapter level. The excellent manner in which this was accomplished was due in no small part to the activities of the Regional Directors and others concerned with the regional setup. This same regional organization can be expected to facilitate the future health and growth of the Society.



ASHRAE Laboratory and Societ Re

The first fiscal year of ASHRAE ended June 30, 1959, and the Research and Technical Committee has made its report to the Board of Directors. As this is also of interest to the members, the complete report has been printed and appears in this issue of the JOURNAL. The Committee always invites comments and suggestions from members, and this year the invitations are particularly significant as the research program and Research Laboratory of the Society are in a position to serve on a broader basis than was possible before the merger. Suggestions can be most helpful when the scope and range of the Society research facilities are understood. Yet it is felt that the membership of the Society is not adequately familiar with the Research Laboratory and its accomplishments. Consequently, a brief history and description of the Laboratory, along with the comments concerning current operations appears to be in order at this time.

HISTORY OF THE LABORATORY

The decision to set up a Research Laboratory was made by a predecessor Society, then known as the American Society of Heating and Ventilating Engineers, in the year 1918. Prior to this, Committees in that Society had been faced with problems relative to the performance of boilers, heating of buildings, the effectiveness of different types of radiators, the absence of standards for ventilation, and a lack of knowledge as to the effect of varying environments on people. In spite of the efforts of the committees, it had become obvious that needed knowledge could not be obtained at a sufficiently rapid rate from industrial tests and investigations. Moreover, much of the information at hand was not accurate and largely represented opinion. Facts in contrast to opinion were needed, and these could best be obtained in a research laboratory unfettered by prejudice.

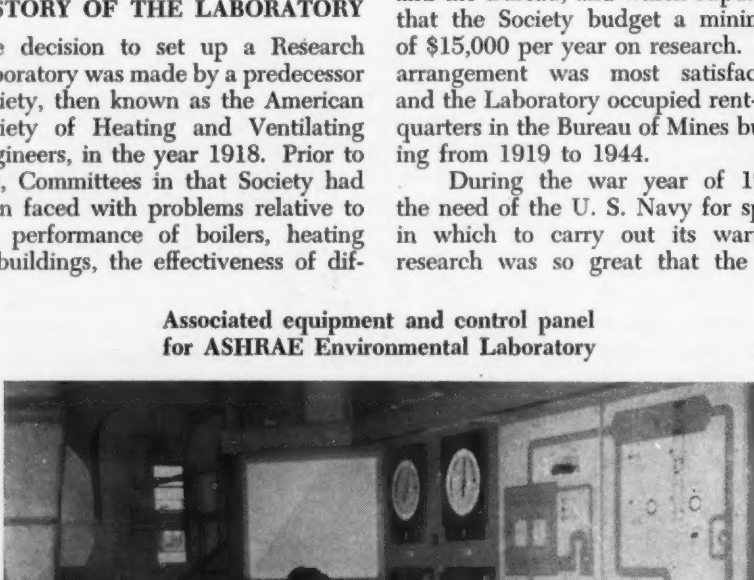
The first Laboratory was thus established in 1919 using space in the Bureau of Mines building in Pittsburgh. The Society entered a cooperative agreement with the Bureau of Mines which called for interchange of information between the Society and the Bureau, and which stipulated that the Society budget a minimum of $15,000 per year on research. The arrangement was most satisfactory and the Laboratory occupied rent-free quarters in the Bureau of Mines building from 1919 to 1944.

During the war year of 1944, the need of the U. S. Navy for space in which to carry out its wartime research was so great that the Research Laboratory found it necessary to leave the Bureau of Mines, and the Laboratory was moved to temporary quarters in Cleveland. In 1946 the present site and buildings were purchased and have been in use to the present time.

This facility consists of an office building and the main laboratory building. The latter, which was originally built in 1935 as a two-story social building and auditorium, is of massive construction with high ceilings and is well suited for research activities. The frame office building was built during the 1880-90 decade. While it has been renovated, it is old in age and styling and it is difficult to make efficient use of much of its area.

Adequate parking space exists in the rear of the Laboratory and a third building at the very end of the lot completes the Laboratory plant. This small building houses the Solar Calorimeter. The Calorimeter, which has been in use for twelve years, has provided the means of measuring a number of solar constants and the performance of numerous types of shading devices. Further details on the Laboratory and its staff are presented in the Annual Report.

Associated equipment and control panel for ASHRAE Environmental Laboratory



FORMER RESEARCH

A recent study of the research activities of the Laboratory over the forty years of its existence have brought to light some interesting changes in the research patterns and topics that developed. In the first decade of operation, 1919-1928, the emphasis was on air cleanliness and ventilating, the performance of radiators, burners, and steam, hot-water, and warm-air heating equipment. In addition to this, the problems associated with insulating materials and building construction received serious study. The very important problem of the occupant in his environment in relation to comfort was given maximum attention.

During the second decade, 1929-38, many of these same topics continued to receive attention. How-

R. C. JORDAN
Chairman
Research and Technical Committee

B. H. JENNINGS
Director of Research

Research

ASHRAE's Research Laboratory in Cleveland

ever, more serious attention was given to air flow in the system and the characteristics of dampers, registers, and air distribution. The need for precise methods of calculation of heating and cooling loads required further research on insulating materials, infiltration and solar effects. Investigations relative to the individual and his environment continued, and detailed heat-transfer studies appeared in greater quantity.

The third decade of the research program ran through 1939-1948. Here again, a number of topics previously considered were under continuing investigation. The physiological study patterns made in this period, particularly at the cooperating institutions, gave attention to extreme conditions as well as to those in the comfort region and considered the effects of the environment on people who were not well. Air distribution and air cleaning continued as important aspects. Other phases merited intensive study during this period; one, the effect of solar radiation both through glass and on the building structure. This period also witnessed the construction of the Laboratory's solar calorimeter. The research program contributed also to the development of psychrometric data leading to the production of a precise psychrometric chart. Weather data came in for careful scrutiny in regard to their effects on the heating and cooling load. This decade also saw the start of rigorous analysis studies for panel (radiant) heating.

The last decade, 1949-58, saw the panel and radiant heating studies brought to a successful conclusion with the development of precise design data. Work on air cleaning continued and greater attention was given to air-distribution studies. Heat pumps also received consideration, and the ventilation problem came in for a number of different analyses. This decade also saw greater attention and emphasis being given to the importance of controlling and eliminating noise, both in liquid-flow systems and in air-flow systems. The noise problem as it related to combustion pulsations also received serious study. Analysis of heating and cooling loads came in for consideration on a more rigorous basis, with attention being given to analogue and thermal-circuit analysis approaches. The greatest emphasis during this period was on studies of the individual to his total environment, and for this purpose the new Environment Laboratory was constructed. From it can be expected continuing answers to a large number of problems.

The Laboratory program over a 40-year period has been a rich source for the factual knowledge on which are based many of the engineering computations and plans in use by our industry today. The results of the work have appeared as papers and articles, in the Transactions and in directly usable form, scattered throughout the GUIDE and DATA BOOK.

FINANCES

The size of the Society research program has greatly expanded during its life period, with the disbursement of $3,192 in 1919 increasing to $30,519 in 1938, to $103,096 in 1948 and to $225,482 in 1958, the last full year for which data are available. Total figures for the last ten years of Society operation (1949 through 1958) may be of interest. During this period the total research disbursements amounted to $1,817,942, and of this sum, $292,534 was used for grants to cooperating institutions. The income to carry out the program consisted in part of $725,389, received as contributions from industry, individuals and foundations. The International Heating and Air-Conditioning Exposition presented to the program an additional $307,671, not all of which was used for operating expenses, the remainder being put into a reserve fund. U. S. Government research contributed a total of $175,559, and the remaining income of $715,274 came as an allocation from membership dues.

PAST AND FUTURE PROGRAMS

In looking back over any program, it is well to consider accomplishments as well as costs. Certainly the contributions from research have been many and varied as is evidenced by the some 350 papers which appeared under the auspices of the program. From this work, much of the basic factual information used by our industry has been established. A critical examination of the references to many of the chapters in the GUIDE will show the extent to which research papers have been used.

However, it is true that in many cases, research projects were activated only after conditions in industry showed that a need for additional fundamental data existed, or that refinements were required in data already available. To a certain extent the problem of factual measurement has placed the Laboratory in an unfortunate position in that, instead of being able to do the pioneer work which could permit it to blaze a trail into new fields and vistas, the Laboratory has most frequently had to cement stones in place after industry or other research outlets had indicated the basic patterns. The pressure to produce factual knowledge has rested heavily on the Laboratory with industry being generous in its support of that research for which the end point is known. There is continuing need for this type of research, but there is also need for the longer range fundamental

research for which there is no immediate objective and for which trust has to be placed in the ability of researchers to work along lines which will be of ultimate benefit both to the Society and to mankind in general. The far-thinking viewpoints of the present Research and Technical Committee are leaning toward the possibility of the Society being able to do more of the fundamental long-range type of research while continuing to serve industry by providing it with working tools as it has effectively done in the past. As some of the future planning is indicated in the accompanying Annual Report, further mention of it will not be made here.

1959 Report of the Research and Technical Committee

This report covers research activities during the five-month period as a merged Society running from February 1 to June 30, 1959. These five months have been a period of transition during which the research activities of the predecessor Societies, ASHAE and ASRE, have been woven into a unified pattern. The previous report of the ASHAE Research Committee appeared just prior to the date of the merger and was published in the January, 1959, issue of the Society Journal.

The Research and Technical Committee was appointed and assumed its functions on January 29, 1959, with a membership consisting of:

R. C. Jordan, Chairman
E. P. Palmatier, Vice Chairman
H. C. Diehl
D. D'Eustachio
S. F. Gilman
F. K. Hick
N. B. Hutcheon
W. T. Pentzer
E. F. Snyder, Jr.
R. M. Stern
W. F. Stoecker
E. R. Wolfert

In addition to the Committee itself, a group of twelve others were named as consultants to the Committee:

P. R. Achenbach
A. P. Boehmer
D. L. Fiske
Albert Giannini
W. C. L. Hemeon
E. N. Johnson
A. M. G. Moody
Maurice Nelles
H. B. Nottage
F. G. Peck
E. J. Robertson
P. H. Yeomans

ORGANIZATIONAL PATTERN

One of the first problems to face the new Committee was to set up its organizational pattern and a method of operation. For this purpose the Chairman, Vice Chairman, and the members who could be contacted, assembled for a short meeting on January 29, 1959, in Philadelphia. At this time, the Chairman named the Executive Committee as follows:

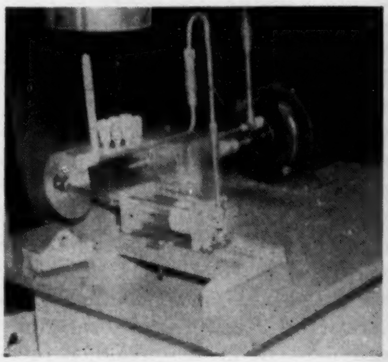
R. C. Jordan, Chairman
E. P. Palmatier, Vice Chairman
N. B. Hutcheon
W. T. Pentzer
E. F. Snyder, Jr.

with R. C. Cross, Technical Director, and B. H. Jennings, Director of Research, to serve as ex-officio, nonvoting members of both Committees.

A meeting of the Executive Committee was held at the Laboratory in Cleveland on March 11, and the full Committee met at the Laboratory in Cleveland on April 10.

In developing an organizational pattern, the Research and Technical Committee endeavored to combine the best features of the Committee patterns which were employed in both Societies. ASHAE was unique among major engineering societies in its strong encouragement of research activities with support provided by the assignment of a fraction of membership dues to the research program. This stimulation of research has, over the years, paid high dividends, in research achievement and research leadership to the industries with which the Society has been associated and has gained for the Society the respect of the other engineering societies, as well as such groups as the National Research Council and the Engineers Joint Council. It is regarded as paramount that these research activities be expanded to cover the additional fields of refrigeration and that the research program be safeguarded in all respects. The research program in ASRE was limited in scope, but in contrast, the technical committee structure of ASRE was outstandingly developed for the technical and technological functions to be performed. Both the research function and the technological and related publication function are extremely important, and thus a structure which would best accomplish the end results was sought as the development pattern was planned.

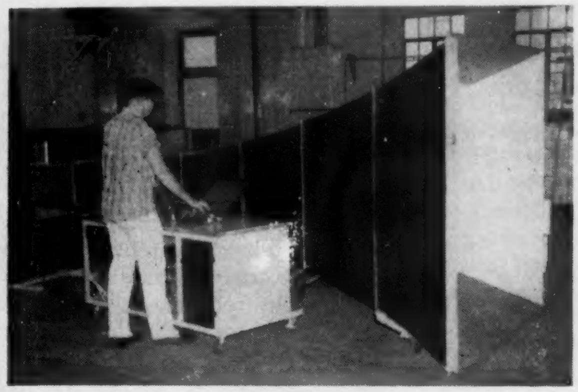
The Research and Technical Committee, after extensive deliberation, recommended to the Board of Directors that the Committee be divided into two major divisions, a Research Division and a Technical Division.



Piston-operated tobacco-smoke generator for use in odor-test-room studies

The Research Division is to be established with six research groups, formed functionally. These are to be (1) *Energy Transfer*, (2) *Mass Transfer*, (3) *Energy Conversion*, (4) *Environment*, (5) *Materials*, and (6) *System Analysis*. To these functional divisions will be referred the research problems of the Society and the research groups in turn will establish from time to time such Panels as are necessary to perform individual and specific tasks assigned. The membership of these Panels is to be drawn from any areas of Society or non-Society membership as deemed advisable, but in each case, at least one member is to be appointed from an appropriate Technical Division Committee. Once the task of a Panel has been completed, a Panel is to be automatically discharged. Thus a Panel may be required to meet once or the task assigned may continue for a year or more, but there is to be no self-perpetuation of the Panel once the function has been completed. These Panels are to be formed to provide specific advice when necessary on the

acceptance or rejection of research grants, for advice on research projects when such advice is needed, or to review the progress of a particular research project or area. Panels might also be formed to provide advice on such topics as, for example, a basic Society policy on psychrometry and psychrometric charts for use in normal, high, or low temperatures. By this pattern of Panels, those persons best qualified for advising on a particular task and possessing intense interest in an area can be drawn both from within and outside the Society. In many ways these Panels will serve a similar function to that which has been carried on so effectively by the former Technical Advisory Committees of ASHAE. However, because of the functionally designed organization which can allocate assignments before panels are appointed, it will be possible to eliminate the overlapping patterns which occasionally developed in the Technical Advisory Committees.



Exponential horn termination used in sound-attentuation studies.

Subjects in test room of Environmental Laboratory engaged in sedentary activities

In the new pattern for the Research Division, the results accomplished by the Research Advisory Committees will in no way be weakened, as the six divisions with the advisory panels under them will continue the exceptionally fine functional activities of the Advisory Committees.

In the Technical Division, there are to be established eight technical committees to be divided into such categories as (1) *Basic Theory and Materials*, (2) *Systems*, (3) *Heating and Refrigeration Loads*, (4) *Environmental Control and Effects*, (5) *Basic Equipment*, (6) *Auxiliary Equipment*, (7) *Unitary Equipment*, and (8) *Products and Processes*. Under each of these technical committees, there will be established subcommittees corresponding to the technological interests of the Society. The Technical Division thus forms a pool of technological information to perform such services as may be required by the Society. These subcommittees have a continuing function for reviewing papers, answering technical inquiries and also preparing material for the DATA BOOKS and other publications.

In order to develop operational procedures and an operational guide for implementation of this plan, a subcommittee, chaired by E. F. Snyder, Jr., has been appointed, and it is planned that the first draft of the Operational Guide be ready for discussion by the Research and Technical Committee at the Lake Placid meeting. It is hoped that the transition be made as rapidly as possible following approval of intent by the Board of Directors.

No particular problems of transition are envisioned insofar as the Research Division is concerned, but since the former ASRE technical committees are temporarily attached to the Publications Committee, the reorganization of the latter group must proceed with care. Current working committees cannot be discharged in this transition since many of these are involved in writing assignments which will continue for some time. Therefore, it is planned that, where necessary, to continue the identity of those technical committees, now subcommittees of the Publications Committee, until their assignments are ended. However, where it is possible without hardship to combine the activities of a technical committee with other committee activities, this will be done.

LABORATORY RESEARCH PROJECTS

Environmental Studies. The Environmental Laboratory constructed inside of the main laboratory is now in active usage. In this carefully instrumented and controlled building, constructed at a total cost in excess of $125,000, is the environment test room, 12 ft wide, 24½ ft long, with a ceiling of variable heights adjustable from 6 ft to 11 ft. The air in this room can be changed up to fifty times an hour, and the walls of the room can have their surfaces controlled separately to provide a wide range of surface temperature conditions for studying radiant effects. The immediate studies being carried out involve the determination of fundamental data to be used in re-evaluating the comfort chart. A test series under fall and winter conditions has been completed, and the summer series is scheduled for 1959. Prior to this, a group of subjects was carried through a warm pattern in the 80 - 105 F range. Subsequent tests envisage a careful study of subjects in the space under various radiant wall conditions with walls, both at the air temperature and differing greatly from the air temperature, maintained in the space and both under symmetrical patterns and asymmetrical patterns of radiation. Thought is also being given to some preliminary studies regarding the effect of ionization on subjective comfort and performance.

Steam Flow Studies. Tests are actively under way to redetermine the steam-flow capacity of copper and steel pipes. This project was inaugurated after it was found that the pipe size recommendations in the GUIDE gave evidence of being oversized in some ranges. Analytical recomputation at the Laboratory showed the differences which had been indicated and strongly pointed to the desirability of experimental clarification. Much data have already been accumulated, and some

Contributors to the ASHRAE Research Program

For the Calendar Year January 1 to December 31, 1958
and to the Beginning of the 1959-60 ASHRAE Fiscal Year, July 1, 1959

Adams, Inc., Henry
Aerofin Corporation
Air Devices, Inc.
Air Filter Corporation
Airkem, Inc.
Air-Maze Corporation
Air Moving and Conditioning Association
Aluminum Company of America
American Air Filter Company, Inc.
American Gas Association, Inc.
American Window Glass Company
Amick Sheet Metal Works
Anemostat Corporation of America
Armstrong Cork Company
Austin Company

Barber-Colman Corporation
Barnebey-Cheney Company
Bell and Gossett Company
Birchfield Boiler, Inc.
Blue Ridge Glass Corporation
Borg-Warner Corporation—Reflectal Corporation
Bouillon, Griffith and Christofferson
Breidert Company, G. C.
Breneman-Hartshorn, Inc.
Bridgers and Paxton
Brookside Corporation
Buensod-Stacey, Inc.
Buffalo Forge Company
Burnham Corporation
Byers Company, A. M.

Cambridge Filter Corporation
Carnes Corporation
Carrier Corporation
Celanese Corporation of America
Chrysler Corporation, Airtemp Div.
Clarage Fan Company
Clarke, John H.
Columbia Boiler Company of Pottstown
Continental Air Filters, Inc.
Copper and Brass Research Association
Cosentini Associates
Crane Company

Detroit Stamping Company
DeVilbiss Company
duPont de Nemours and Company, Inc., E. I.

Economides, L.
Egli and Gompf, Inc.
Elliot and Company, Inc., Edwin
Evans, Bruce L.

Farr Company
Forslund Pump and Machinery Corporation

Garden City Fan Company
General Motors Frigidaire Div.
Green Fuel Economizer Company, Inc.
Gritschke and Associates, E. R.
Gustin-Bacon Manufacturing Company

Hartzell Industries, Inc.
Henry Valve Company
Hoffman Specialty Manufacturing Corporation
Hydrotherm, Inc.

Ilg Electric Ventilating Company
Illinois Shade Cloth Corporation
Industrial Acoustics Company, Inc.
Insulation Board Institute
Iron Fireman Manufacturing Company

Jaros, Baum and Bolles
Jenn Air Products Company, Inc.
Johns-Manville Corporation
Johnson and Johnson
Johnson Service Company

Kahn, Albert, Associated Architects and Engineers, Inc.
Koppers Company, Incorporated Metal Products Div.
Kroeker and Associates, J. Donald

Lau Blower Company
Leopold, Charles S.
Leslie Company
Libbey-Owens-Ford Glass Company
Lockport Mills, Inc.

Marley Company
McDonnell and Miller, Inc.
Mechanical Contractors Association of Chicago
Mechanical Contractors Association of Philadelphia, Inc.
Mechanical Contractors Association of Seattle
Metals and Controls Corporation
Minneapolis-Honeywell Regulator Company
Modine Manufacturing Company
Monsanto Chemical Company
Morris Engineering Company
Morrison, W. Bruce

Nash Engineering Company
National Mineral Wool Association
National-U. S. Radiator Corporation and Divisions and Subsidiaries

Owens-Corning Fiberglas Corporation
Owens-Illinois (Kimble Glass Company)

Philadelphia Electric Company
Pittsburgh Corning Corporation
Pittsburgh Plate Glass Company
Porter, Urquhart, McCreary and O'Brien
Powers Regulator Company

Raisler Corporation
Research Products Corporation
Reynolds Metals Company
Roberts-Gordon Appliance Corporation
Robertshaw-Fulton Controls Company, Fulton Sylphon Div.

Schoenijahn, Robert P.
Seelye Stevenson Value & Knecht
Smith Company, Inc., H. B.
Spence Engineering Company, Inc.
Spohn Heating and Ventilating Company
Stinard, Rutherford L.
Surface Combustion Corporation

Technical Filter Company
Torrington Manufacturing Company
Trane Company
Trion, Inc.
Tyre Brothers Glass Company

Vermiculite Contractors, Inc.
Voorhees Walker Smith and Smith
Vortox Company

Waterloo Register Company, Inc.
Webster and Company, Warren
Weil-McLain Company
Weiss and Company, Carl
Western Blower Company
Westinghouse Electric Corporation
White-Rodgers Electric Company
Whitman, Requardt and Associates
Whittlesey, R. L.
Wing Manufacturing Company, L. J.
Wiremold Company
Wolff and Munier, Inc.
Worthington Corporation

Zonolite Company

interesting and rather unexpected patterns of condensation carry-over have been brought to light.

Solar Calorimeter. The solar calorimeter at the Laboratory is in intensive use whenever sun and cloud conditions are suitable. In the recent past, work on metal and canvas awnings has been completed, and more recently shades and drapes were investigated. At the present time, studies are being made on between-glass shading devices. Plans are also under way relative to carrying out a program which will study plastics domes.

Infiltration Studies. A continuing phase on the study of infiltration is now under way concerned with the performance of revolving doors. For this purpose, a representative full-size revolving door has been installed in a specially constructed entrance of the Laboratory. The entrance is backed up by a carefully sealed structure so that uncontrolled leakage can be eliminated. The air flow through the door is being carefully measured under a variety of conditions, such as continuous rotation, in still position, and with people moving through at timed rates. Various methods of detecting leakage air flow are being employed, one of which involves the technique of an inert gas.

Human Calorimeter. Six years ago the Laboratory completed the design and construction of a human calorimeter. This was built for the Navy and delivered to the Naval Medical Research Institute where it has been extremely useful in providing fundamental data on the performance of the human system under a variety of conditions, some of them involving extreme stress. At the request of the Navy, the Laboratory entered into the construction of a modification of the calorimeter to increase its flexibility and utility. This design and construction work is now under way.

Noise and Sound Level Studies. The Laboratory has been working under a contract with the United States Navy to study the effect of turning vanes and elbows in complex duct systems. This work is of importance not only to the Navy but to designers faced with the problem of sound generation and attenuation in duct systems. A large portion of the experimental work has already been completed and a report released to the Navy. As none of the work is of a restricted nature, it is expected that a paper for Society use can be prepared in the very near future.

Odor Program. The odor program was mentioned elsewhere in this report, and plans are under way for experimental testing to start in July, 1959.

General. In addition to the major research projects under way at the Laboratory, a number of analytical studies are being carried out by staff members. With the continuing help and advice from Advisory Committees, a backlog of research projects is at hand; and new projects can be activated at any time that facilities and staff become available.

The Laboratory staff participates in technical meetings at the Laboratory, endeavors to provide answers to requests for information of a fundamental nature, and holds itself in readiness to give technical talks, when these do not interfere appreciably with the conduct of the research programs. A series of papers are continuously in production by members of the staff, and at Annual and Semiannual Meetings of the Society, three or more papers are usually given by staff members.

RESEARCH ADVISORY COMMITTEES

To continue the fine work of the Technical Advisory Committees, a similar set of interim committees was appointed under the name of Research Advisory Committees. In the past, these committees have served to advise the research program both at the Laboratory and at cooperating institutions. They have helped bring about the close cooperation of the industry and profession with research activities and have been of assistance in reporting on research activities relative both to research papers and the GUIDE. During the period covered by this report, eighteen committees have been appointed. The membership of these Committees was published in the May, 1959, issue of the ASHRAE JOURNAL, and the names are not repeated here.

At the Philadelphia meeting in January, 17 of the predecessor Technical Advisory Committees held meetings, and six Research Advisory Committee meetings were held at the Annual Meeting of the Society in June. Several committee meetings were held at the Laboratory in Cleveland during the spring.

On April 22 the RAC on Hot Water and Steam Heating met and discussed a number of topics relative to research in its field of interest, with particular attention being given to the research project being carried on at the Laboratory relative to steam flow in piping systems and to the cooperative research projects at Northwestern University and at the University of Illinois.

The Research Advisory Committee on Odors met at the Laboratory on April 29 and outlined a research program which will get under way in the Laboratory early in the summer of 1959. One of the first objectives of this program will be to study the various methods of odor control now available. For this purpose, four odor types will be set up for examination in the Laboratory odor test rooms; and, in connection with these, a series of tests will be run to investigate control techniques.

On April 30 and May 1 the RAC on Insulation met at the Laboratory and reported through its subcommittees of the progress being made on evaluating various types of insulation, both for insulation effectiveness and relative to moisture migration.

The RAC on Combustion appointed a Guiding Committee to plan the Combustion Conference. This Committee met twice at the Laboratory on March 5 and April 16 and, during these two meetings, laid plans for the Combustion Conference which was held May 21 at the Laboratory. At this meeting approximately 100 people heard 11 panel speakers discuss various topics relative to Combustion in the Heating Industry. The purpose of the Conference was to delineate the status of combustion in our profession and to determine research needs relative to it. The Conference brought out the fact that while combustion research and development has made enormous strides in other fields, such as for jet aircraft and rockets, in the less spectacular field of combustion for heating purposes, progress has been at a much slower rate. The conference suggested several fields that apparently merited serious study, and the RAC on Combustion and the Laboratory staff are planning to analyze carefully the conclusions reached by those in attendance at the Conference. Conference proceedings were reported in the ASHRAE JOURNAL August issue.

FINANCES AND EXPENDITURES

The research program of the Society obtains its support from four sources, the first being a fraction of the membership dues; the second, a significant contribution for research which has been made to the Society by the International Heating and Air Conditioning Exposition; third, contributions made to the research program by industrial firms, associations, and individuals; fourth, funds received for research projects of broad interest carried out for the United States Government and for foundations.

For the five-month period covered by this report, an interim budget amounting to $112,000 was approved by the Research and Technical Committee and by the Executive Committees of the Society, and expenditures will remain within this sum, reaching a final figure of $104,041.

At the meeting of the Research and Technical Committee held at the Laboratory on April 10, a budget for the coming fiscal year starting July 1, 1959, and ending June 30, 1960, was recommended in the amount of $324,500; and at the meeting of the ASHRAE Executive Committee, held April 19, 1959, the total budget for research was approved, but with an increase in the total allocated for promotion being added, it reached a figure of $328,200. It is felt that with this budget the research program can be adequately expanded to cover a number of additional research outlets desired and, at the same time, carry on the programs now under way. In particular, it is desired more intensively to carry out research related directly to refrigeration.

FACILITIES AND STAFF

The ASHRAE Research Laboratory is located in Cleveland at 7218 Euclid Avenue. It consists of two buildings located on a plot of ground containing 1.1 acres. The front building, largely used for administrative activities, contains offices, a library, and conference room. It has a floor area of 5,300 sq ft. The rear building, housing the main research activities, has 13,000 sq ft of usable space. The front building was extensively refurbished in 1958.

The facilities at the Laboratory are complete and adequate for the research programs which are now being carried on. However, for the expanded research program which is being envisaged over the next few years, it is felt that the present site is not satisfactory; and both the Research and Technical Committee and the Building Committee of the Society have been actively investigating the possibility of finding another site, either in Cleveland, or in another city.

The research staff at the Laboratory consists of an administrative staff, project engineers, assistants, a librarian, secretarial and maintenance staff. Of the current staff of twenty-five, eleven members are of professional level. In addition to the perma-

(*Continued on page* 82)

Research, creativity

and the ASHRAE

RICHARD C. JORDAN
Chairman, Research
and Technical Committee

"Fundamental research is often the most effective possible applied research but with a long time-factor involved." This recognition that the most useful and startling applications of research in our society stem originally from the work of creative people allowed to search for knowledge without knowing to what specific ends the results may be placed was but one of many stimulating ideas which this writer gleaned from a recent conference in which he was invited to participate. Since much of the discussion centered on problems of high importance to ASHRAE during its present reorganization of the Research and Technical Committee activities, this page will this month relate to some of these discussions and conclusions.

The conference was sponsored by and conducted at Harvard University and was entitled "Scientific Creativity in an Organizational Setting." Invitation was limited to approximately 70 with over half drawn from high positions in major corporations located in this and other countries. The others were principally from education and such governmental groups as the National Institutes of Health, the National Science Foundation, the Office of Naval Research, and the National Coal Board of England.

This microscopic examination of the nature and fostering of creativity was initiated by Dr. J. Bronowski, Director-General of the Process Development Department of the National Coal Board of England. In a sweeping inspection Dr. Bronowski first made the point that to think creatively implies an approval of change and that many societies in the history of the world have refused to accept change as desirable. This is particularly true of animal societies other than the vertebrates. For example the insect groups in some cases for thousands of years have often refused and even combated change so that practically no evolutionary modifications have resulted. The acceptance of change by man has varied widely between civilizations. The second point made by Dr. Bronowski was that to create implies a giving of value to the making of things.

The contemplative life, rather than the active life, has been valued more highly by a number of civilizations, notably in the Oriental countries. That is, the "making of things" is not always regarded with as high value as in many of the Western civilizations, particularly our own. The third point made was that creativity implies expression of personality and not regimentation. Thus creative individuals are by nature anti-authoritarian and even anti-social in many respects. The fostering of creativity implies approval of change, a value to things rather than to contemplation, and a value to the expression of personality rather than anonymity. The paradox of society is that in fostering scientific creativity it is fostering by its very nature those things which tend to destroy a stable society.

If we accept creativity, controlled change and scientific advances as desirable and even necessary in this world of competitive ideologies, we must be extremely careful that we do not stifle creativity by over-organization. Dr. Emanuel R. Piore, Director of Research of International Business Machines Corporation, aptly pointed out that we are all willing to accept the great creative engineering achievement associated with the name of Alexander Graham Bell. Yet he questions whether in the present day pattern of "justification . . . . in terms of market, in terms of return on investment, in terms of profit" that the telephone could have developed as easily today. In his words, "Using the contemporary techniques of operational research and market analysis and projecting them to the time of the invention of the telephone, it would have been concluded that there was no need for a telephone since rapid communication could be obtained via the telegraph, at length via the mails, and the telephone was an interesting instrument for the amusement of children and women. If such an analysis were made, using contemporary analytic techniques, I am sure the Boston banks would never have backed Mr. Bell . . . . . ."

In this same vein, Dr. H. B. G. Casimir, Director, Phillips Research Laboratory, The Netherlands, concluded that true fundamental work has been rarely carried out in industrial laboratories and that this should be a "warning that thorough organization and planning of research on a nation wide basis might well turn out to be detrimental to fundamental research." The point was further elaborated by Dr. W. D. Lewis, Director of Research, Bell Telephone Laboratories, Incorporated, who indicated "limitation of goals is in some sense a limitation of freedom, whereas the creative individual and his creativity traditionally thrive best in an atmosphere of maximum freedom."

(*Continued on page* 106)

New method of

Chimney design

and performance evaluation

This presentation of a practical design method for the sizing of chimneys is based on the theories and tests outlined previously in "Fundamental Analysis of Chimney Performance" (4). The theory is general and is not limited to any specific size of chimney; industrial or small residential chimneys may be treated in the same manner. The design graphs apply to chimneys with heights up to 80 ft and flue gas flow rates up to 600 lb/hr, but these values may be extended easily by the theories presented here and in the earlier paper.

The design method yields, first of all, the chimney diameter required based on a given set of conditions. This diameter results in a chimney of maximum efficiency. The second step in the design is the determination of the actual draft which will be obtainable under the same set of given conditions. If the actual draft found is not sufficient for the appliance being served, then the chimney height or the inlet temperature must be increased. If the draft is found to be greater than that required then the usual means of draft control, e.g. installation of a draft regulator, may be used.

The ratio of actual draft to theoretical draft is the chimney efficiency; the actual being less than the theoretical by two factors: friction and heat loss. If both these losses are accurately evaluated then the actual draft may be determined. In general, this is the procedure followed.

The design method presented here is based on steady state conditions and no account is taken of the effects of infiltration and wind.

W. C. Moffatt is Lecturer, Dept of Mechanical Engineering, Royal Military College of Canada. Professor W. G. Colborne is with the Dept of Engineering, Assumption University of Windsor. This paper is based on the M.Sc. thesis of W. C. Moffatt and was presented at the ASHRAE annual meeting, Lake Placid, N. Y., June 22-24, 1959.

W. C. MOFFATT
Member ASHRAE

W. G. COLBORNE
Member ASHRAE

Theory—For a clear understanding of the design graphs, some theory beyond that presented in the first paper will be necessary, principally in the treatment of heat loss.

The efficiency drop due to friction is given by $\dfrac{K\rho_1 V_1^2}{2\Delta\rho g H}$ where K may be evaluated as follows:

for $N_R > 3100$

$$K = f\left(\frac{L}{d}\right) + 52f^{1.00}$$

for $N_R < 3100$

$$K = f\left(\frac{L}{d}\right) + 25\left(\frac{H}{d}\right)^{0.5}$$

The expression for chimney efficiency is (1)

$$\frac{D}{\Delta\rho g H} = \frac{\Delta\rho_m}{\Delta\rho}\left(1 - \frac{K\rho_1 V_1^2}{2\Delta\rho g H}\right) \quad (1)$$

This expression accounts for heat loss from the chimney if $\Delta\rho_m$ is the density difference $(\rho_o - \rho_m)$ where ρ_m is the density corresponding to a mean temperature T_m. This mean temperature is that temperature which if it existed throughout the chimney would result in the same draft condition as would occur if the gas entered at T_1 and left at T_2.

The case of the thin-walled metal chimney in which the wall has negligible resistance to heat flow will be considered first. For this case, the inside and outside surface films account for the only resistances to heat flow. The inside film coefficient may be evaluated (2) from the expression

$$\frac{h_i d}{k} = 0.023\left(\frac{dG}{\mu}\right)^{0.8}\left(\frac{C_P\mu}{k}\right)^{0.4}$$

Using air or flue gas within the limited temperature range under consideration, $\dfrac{C_P\mu}{k} = 0.74$ with little error. Therefore the expression reduces to

$$\frac{h_i d}{k} = 0.0204\left(\frac{dG}{\mu}\right)^{0.8}$$

or

$$h_i = 0.0204\left(\frac{k}{d}\right)\left(\frac{dG}{\mu}\right)^{0.8}$$

The conductivity for air is taken as

$$k = 0.0133 + 2.39 \times 10^{-5}\, T_g$$

where T_g is the flue gas temperature.

For the purposes of this analysis, the gas properties may be evaluated at the chimney inlet temperature with sufficient accuracy. The absolute viscosity was evaluated at 500F and assumed constant at 0.0679 lb/ft-hr.

The resulting equation for the resistance term would be

$$R_i = \frac{1}{h_i} = \frac{d^{1.8}}{(2.71 \times 10^{-4} + 4.88 \times 10^{-7}\, T_1)\,(18.8\, w)^{0.8}} \quad (2)$$

The outside film coefficient for heated vertical flues (2) is given as

$$h_o = 0.29\left(\frac{T_s - T_o}{d}\right)^{0.25} \qquad (3)$$

The surface temperature T_s may be evaluated from

$$T_s = T_1 - \frac{R_i}{R_i + R_o}(T_1 - T_o)$$

Combining these two equations the relationship may be stated

$$\frac{(R_i + R_o)}{R_o^5} = \frac{0.0071}{d}(T_1 - T_o) \qquad (4)$$

The value of the mean chimney temperature T_m (1) can be found from

$$T_m = T_1 - 0.65\,(T_1 - T_2) \qquad (5)$$

We must therefore evaluate T_2 in order to use this expression.

$$dQ = wC_P\,dT_1 = U\,\Delta T\,da$$

$$\int_{T_1}^{T_2} \frac{dT_1}{T_1 - T_o} = \frac{U\,a}{w\,C_p} = \frac{U\,A\,L}{w\,C_P}$$

$$\therefore \quad \ln\left(\frac{T_1 - T_o}{T_2 - T_o}\right) = \frac{U\,A\,L}{w\,C_P}$$

$$\frac{T_1 - T_o}{T_2 - T_o} = e^{\frac{UAL}{w\,C_p}} \qquad (6)$$

The U value in this equation is for the chimney wall and in the special case of the aluminum wall

$$U = \frac{1}{R_i + R_o}$$ where R_i and R_o have been determined. The values of T_2 as calculated agreed with experimental values in all cases. The maximum difference noted was 8 with the majority being within 2.

The mean temperature T_m can then be calculated from equation (5) above.

For the case of a thick-walled, e.g. masonry chimney, the resistance to heat flow of the wall must be considered. In addition, when the wall thickness is of the same magnitude as the inside dimensions of the chimney, a shape factor is normally introduced and the normal conduction equation becomes

$$q = S\,k\,\Delta T$$

For a rectangular flue

$$S = \frac{P}{\Delta x} + 2.16 \text{ ft per ft of length}$$

and for a circular flue in a square chimney

$$S = 2 \times 10^{\frac{1.35d}{b}}$$

where d = flue diam.

b = length of one exterior side of chimney

It may then be expressed

$$U_1 = \frac{1}{R_1 + \frac{A_1 R_o}{A_o} + \frac{A_1}{Sk}} \qquad (7)$$

where U_1 is the overall heat transfer coefficient to be used with the inside surface area.

As was seen previously R_o could only be found after R_1 was known. The inside resistance now used is

$$R_I = R_1 + \frac{A_1}{Sk} \qquad (8)$$

This value for R_I is then used in the calculation of R_o.

Equation (6) is again used to determine T_2 with $V_1 \times A_1$ replacing $V \times A$. Once having T_2 the value of T_m may be found as before. Then T_m is used to calculate the mean density ρ_m and from this $(\rho_o\text{-}\rho_m)$ is found.

This completes the theoretical treatment of chimney losses, and makes possible a relatively simple and reliable method of evaluating performance. In order to further simplify the design, graphical solutions of the above equations have been developed.

Graphical solution of chimney performance—In starting the design of a chimney, the following factors are normally known:

flue gas temperature	T_1
chimney height	H
required draft	D_R
flue gas weight flow	w

In addition to these there are other factors, the values of which must be assumed. For the development of the graphs it was assumed that the ambient air temperature T_o was 60F, and the relative roughness of the flue was 0.001.

From the experimental results it was seen that the chimney effi-

Fig. 1—Graph for determination of optimum chimney size

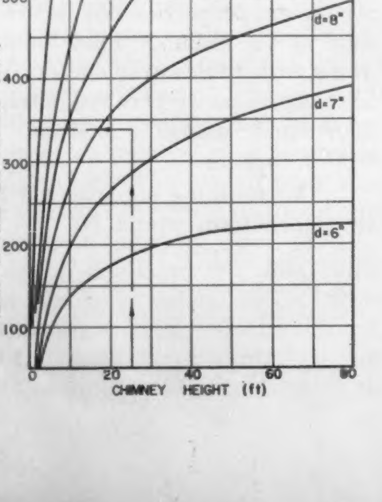


Fig. 2—Graph for determination of inside film resistance R_1

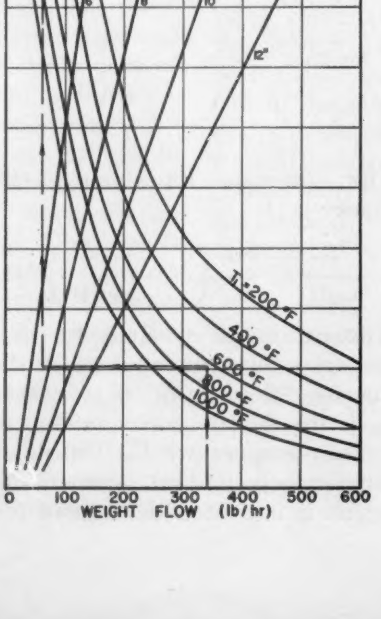
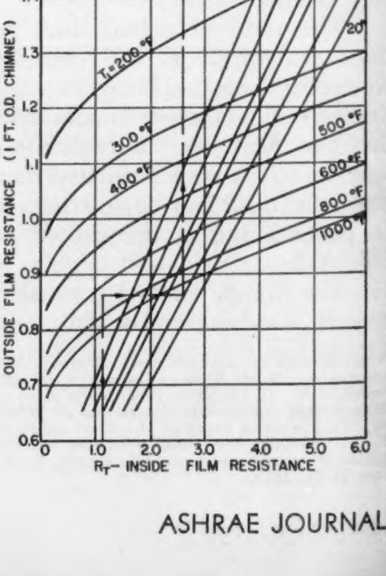


Fig. 3—Graph for determination of outside film resistance R_o



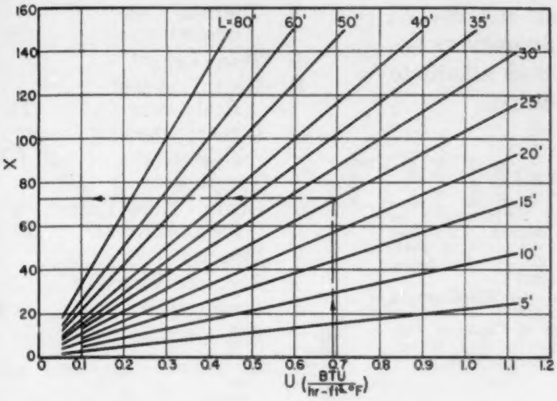


Fig. 4—Graph for determination of X

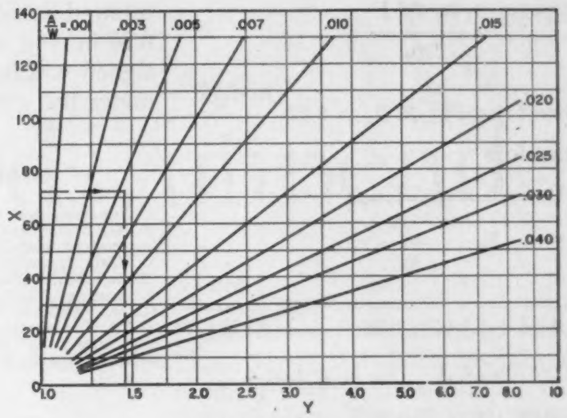


Fig. 5—Graph for determination of Y

ciency reached a maximum at or near $\frac{K\rho_1 V_1^2}{2\Delta\rho g H} = 0.1$. For purposes of design it is desirable to choose conditions which will approximate this point of maximum efficiency. Fig. 1 is the solution of this expression and from it the chimney inside diameter may be found. Rectangular equivalents may be used in place of the round size as found. Fig. 1 was plotted assuming the flue gas temperature at the chimney inlet was between 400 and 600F. However, this same graph may be used with temperatures between 300 and 700F with acceptable accuracy.

Step 2 of the calculation is the determination of the actual draft which will be available in this size of chimney under the given conditions.

The actual chimney efficiency may be found from equation (1). This equation however, reduces to

$$\frac{D}{\Delta\rho g H} = \frac{\Delta\rho_m}{\Delta\rho}(1 - 0.1)$$

or $D = 0.9\,\Delta\rho_m\, gH$

$\Delta\rho_m$ is found by the method outlined in the theory.

Fig. 2 gives the solution of equation (2) and yields a value for R_1, the inside film resistance to heat flow. For a chimney with a wall having an appreciable resistance to heat flow, the total inside resistance term must be calculated from equation (8). The thermal conductivity of the chimney material may be found from the normal sources of heat transfer data. Having found R_I Fig. 3 may now be used to give the solution of equation (4). This gives the value of R_o, the outside film resistance.

Using these values of R_I and R_o, U, the overall heat transfer coefficient, may be calculated from

$$U = \frac{1}{R_I + \frac{A_i R_o}{A_o}}$$

Using Figs. 4, 5 and 6 the values of X, Y and T_2 may be found and from equation (5). T_m may now be calculated.

The actual draft for the given chimney is then determined from

$$D = 6.86\,H\left(\frac{1}{T_o} - \frac{1}{T_m}\right) \quad (9)$$

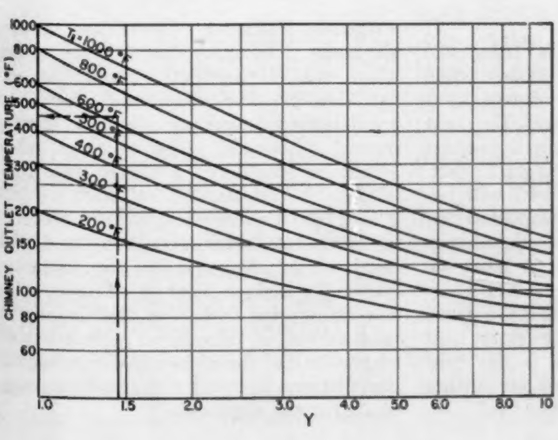


Fig. 6—Graph for determination of exit temperature T_2

where the temperature T is in absolute degrees or $T = F + 460$. The draft D in this equation is in inches of water.

Sample solution — Given: fuel rate —16 lb per hr of oil; CO_2 in flue gas —10%; chimney height—25 ft; chimney construction — common brick; flue gas temperature — 650 F.

Solution: Flue gas flow rate = 340 lb/hr (3). From Fig. 1 the chimney diameter for maximum efficiency is seen to be between 7 and 8 in. The smaller diameter is chosen since it results in a lower efficiency drop than does a chimney of larger size. This can be seen from performance curves.

Allowing for liner thickness, mortar and bricks, the exterior dimensions of the chimney will be 16×16 in.

To determine the chimney exit temperature, the following values will therefore apply:

Inside Surface Area/ft-length
$A_i = 1.83\ ft.^2$
Outside Surface Area/ft-length
$A_o = 5.33\ ft.^2$
Thermal Conductivity
$k = 0.48\ \frac{Btu}{hr\text{-}ft\text{-}F}$
Shape Factor
$S = 2 \times 10^{\frac{1.25 \times 7}{16}} = 7.07\ ft.$
$A_i/A_o = 0.344$
$A_i/Sk = 0.54\ \frac{hr\text{-}ft^2\text{-}F}{Btu}$
$A_i/w = 0.0054\ \frac{ft^2\text{-}hr}{lb}$

From Fig. 2, $R_i = 0.60\ \frac{hr\text{-}ft^2\text{-}F}{Btu}$ and therefore

$$R_I = R_i + \frac{A_i}{Sk} = 0.60 + .54 =$$

$$1.14 \frac{\text{hr-ft}^2\text{-F}}{\text{Btu}}$$

Then from Fig. 3, $R_o = 0.92 \frac{\text{hr-ft}^2\text{-F}}{\text{Btu}}$

Therefore

$$U = \frac{1}{R_i + \frac{A_i R_i}{A_o}} =$$

$$\frac{1}{1.14 + 0.344 \times 0.92} = 0.69 \frac{\text{Btu}}{\text{hr-ft}^2\text{-F}}$$

From Fig. 4, $X = 72$, from Fig. 5, $Y = 1.45$ and from Fig. 6, $T_2 = 450$ F.

Therefore,

$$T_m = T_1 - .65\ (T_1 - T_2) = 650 - .65\ (650 - 450)$$

$$= 520 \text{ F} = 980 \text{ R}$$

Hence the actual draft in the chimney is

$$D = 6.86\ H \left(\frac{1}{T_o} - \frac{1}{T_m} \right)$$

$$= 6.86 \times 25 \left(\frac{1}{520} - \frac{1}{980} \right)$$

$$= 0.15 \text{ in. w.g.}$$

The normal draft requirement for oil-fired furnaces does not exceed 0.06 in. w.g. so the chimney as designed will be more than adequate under the given conditions.

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2. **Heat Transmission, by W. H. McAdams, (McGraw-Hill, New York, 1954).**
3. **Heating, Ventilating and Air Conditioning Guide, (ASHAE, New York, 1958).**
4. **"A Fundamental Analysis of Chimney Performance", by W. B. Colborne and W. C. Moffatt, ASHRAE Journal, March, 1959.**

NOMENCLATURE

Symbol	Quantity	Dimensions
A	Area	L^2
C_p	Specific Heat at Constant Pressure	$H/M\theta$
D	Draft	M/LT^2
d	Diameter	L
od	Outside Diameter of Chimney	L
G	Mass Flow Rate per Unit Area	M/TL^2
g	Acceleration Due to Gravity	L/T^2
H	Height	L
h	Heat Transfer Coefficient	$H/TL^2\theta$
k	Thermal Conductivity	$H/LT\theta$
L	Total Length	L
R	Heat Transfer Resistance	$TL^2\theta/H$
$\rho, \Delta\rho$	Density, Density Difference	M/L^3
T	Temperature	θ
U	Overall Heat Transfer Coefficient	$H/TL^2\theta$
V	Velocity	L/T
μ	Absolute Viscosity	M/LT
w	Weight Flow	M/T

$$X = \frac{UL}{C_p}$$

$$Y = e^{\frac{UAL}{wC_p}}$$

DIMENSIONLESS GROUPS

K	Euler's Number = Isothermal Friction Factor
f	Darcy's Friction Factor
N_R	Reynold's Number

SUBSCRIPTS

$_i$	Inside
$_1$	Chimney Inlet
$_2$	Chimney Outlet
$_o$	Outside
$_s$	Surface
$_m$	Mean

DISCUSSION at Lake Placid upon the conclusion of the presentation of this paper included remarks from which the following have been excerpted.

WILLIAM G. BROWN (submitted in writing) This new study has shown that the non-isothermal friction factor K does not depend only on the Reynolds number Re, but also strongly on the Grashof number Gr, as in natural convection. This dependence on Gr was determined by comparison of K values from isothermal model tests with the values of K determined with the masonry chimney under normal non-isothermal operation. In the masonry chimney the friction loss at low gas flow rates actually tended to become independent of the flow velocity. In addition, flow was turbulent no matter how low the Reynolds number. Only at high flow rates (corresponding to Reynolds numbers of 10,000-20,000) did the non-isothermal values of K approach those of the isothermal model tests. As a consequence of these tests it became clear that the previously reported good agreement between the theoretical performance based on assumed isothermal friction and the performance of the masonry chimney tested by Achenback and Cole was fortuitous. This means simply that it is not yet possible to properly extend test data for other sizes of chimneys as suggested previously by Professor Colborne and Mr. Moffatt.

In order to do this, the manner in which K depends on both Re and Gr must be known. Only for high flow rates can the design method suggested previously be used. In the range of low to moderate flow rates, the chimney efficiency varies sharply with the flow rate from a low value of perhaps 20 to 50% at near zero flow to a peak efficiency of 70 to 90%. Hence errors in the value of K can cause quite large errors in estimating the efficiency for other chimney sizes. Since the flow rates corresponding to maximum efficiency are of greatest interest in chimney design, care must be exercised in interpreting this range.

Professor Colborne We ended up assuming that K would be the function and Reynolds and roughness number, with F in turn, the function of F friction, T over D.

We did not attempt to evaluate the K for the non-isothermal condition.

A. G. WILSON I believe that steady state operation of the heating appliance has been assumed. In any domestic heating system the cycling operation of the unit would occur. A rigorous method of design of chimneys for domestic applications would ultimately have to take into account this non-steady state operation of the appliance and the various in-draft during the heating cycle.

Professor Colborne This is true. We have considered only the steady state operation and as a matter of fact, it is the extension of this problem. The next step was this unsteady state condition and we have given some thought to that. The mass of the chimney wall will become the big factor for consideration there, the time lag involved in the changing of temperature and this is what we have looked into so far, which has really been quite small, is going to be a fairly tricky problem of unsteady state heat transfer conditions. But, it is the next step, certainly, to bring this on further into a rigorous design method.

DAVID LAUGHLIN I would like to call attention to the fact that the initial startup from a dead cold start is the critical time in a residential unit. So that the cycling condition, although I think it perhaps approaches the steady state condition, still the critical condition is the cold start.

There is one more point that is worthy of mention; that is, the variable effect of the barometric draft control on oil fired heaters and the draft on gas fire heaters.

Further complicating the issue, on a cold start condition, you will find an oil-fired unit for exactly that barometric draft control may be nearly closed at the point of start and will open as the unit starts. So, in addition to the normal transient condition, you have the variable control behavior.

I would like to inquire about the effect of wind, not in the flue but in the chimney top and also in the outside coefficient for heat transfer which would affect an outside chimney differently than an inside chimney.

Professor Colborne There are certain problems. The cold start I think is the most critical. Secondly, certain uncontrollable weather conditions where the cycle is for a longer period on and shorter period off would probably reach what could be considered a steady state condition. The problem of cold start, we certainly have done nothing to. Wind effects certainly have an influence. In our design method we designed to the optimum point, the highest point of efficiency with the assumption that some draft reduction method will be introduced such as a draft regulator and therefore upset the original calculations, but will still result in ample draft for the appliance.

New standards impend

A. T. BOGGS, III
ASHRAE Technical Secretary

In an earlier issue, June 1959, page 75, the proposed standards being developed by the Standards Committee were listed. At the recent national meeting in Lake Placid, reports were submitted by the project committees working on prospective or revised standards. Some of these standards are nearing completion and in order to keep the membership abreast of this situation, these standards will be reviewed herewith.

36P–Measurement of Sound Radiating from Equipment–A proposed sound measuring technique to be included in a future standard has been developed by Project Committee 36P. At a recent national meeting, Chairman C. M. Ashley presented a report on this development. The project committee is distributing a number of copies of this proposed technique to representatives of industry in order that it may be field tested. It is hoped that such testing will enable the project committee to include in the final standard recommendations of industry and will result in an overall acceptable standard. The purpose of this procedure is to provide a means for determining the character and amount of sound produced by air conditioning, refrigerating, and heating equipment. Further developments will be reported in this column.

37P–**Unitary Air-Conditioning Equipment** – the final draft of this proposed standard has been approved by the project committee and distributed to the Standards Committee for consideration. The purpose of this standard is to provide test methods for determining the cooling capacity of unitary air conditioning equipment. These test methods have been established for mechanical-compression unitary air-conditioning units or matched assemblies which operate nonfrosting. It is expected that the recommended standard will be published in the JOURNAL prior to the February 1960 Winter Meeting.

39P–**Unitary Heat Pumps for Air Conditioning**–It was reported at the Lake Placid Meeting that the members of this project committee had been appointed. Chairman G. L. Biehn has indicated that the development of a standard for testing unitary heat pumps will be initiated in the near future.

47-35R–**Return-Line Low Vacuum Heating Pumps**–This revision to an earlier ASHVE standard was approved June 10, 1959 by the project committee. The Standards Committee is presently considering the standard and a recommended version will be published in the JOURNAL for consideration by the members prior to the February 1960 Meeting.

41P–**Standard Measurements**–Previously it has been necessary for project committees developing standards to include detailed information relative to the measurement of air flow, pressures, temperatures, etc. The Standards Committee has initiated a project which will present in one standard all such measurement techniques. This will enable future project committees to refer to a standard which already exists rather than repeating in their respective standards such detailed information. Chairman C. W. Phillips has reported that his committee will meet in the near future to consider the scope of their activities and establish plans for future work.

ASA: B31–**Code for Pressure Piping**–New American Standards developed by Sectional Committee B31 have been announced by ASA. These are B31.3–1959, Petroleum Refinery Piping; B31.4–1959, Oil Transportation Piping; and B31.8–1958, Gas Transmission and Distribution Piping Systems. Copies may be obtained from ASA or ASME.

C85–Proposed American Standard ASA C85, **Terminology for Automatic Controls**, has been published by ASME and distributed to industry for comment.

National Conference: ASA has announced the Tenth National Conference on Standards to be held October 20-22 at the Sheraton-Cadillac Hotel, Detroit, Mich.

NFPA: Publication No. 214 Standard on Water-Cooling Towers has been announced by NFPA. Copies are available from NFPA, 60 Batterymarch Street, Boston 10, Mass., at 40c per copy. This new standard on water-cooling towers has been released recently by the National Fire Protection Association. Development of the standard has been occasioned by a series of major fires in cooling towers. Contrary to popular opinion, these towers do burn. The NFPA standard covers location and construction of the towers, installation of electrical equipment, and methods of protecting towers. Usually such towers are inaccessible for manual fire fighting and present a serious fire problem unless protected by automatic sprinkler equipment. The problem has been growing with the rapid increase in air conditioning and in industrial processes requiring large quantities of cool water. The standard, purely advisory as far as NFPA is concerned, is expected to be used widely as a guide by building inspectors, plant protection people, and others who have to deal with this problem. Previously there has been no nationally-accepted guide to follow.

Acoustical

Testing of mufflers

for halogenated hydrocarbon and oil refrigeration systems

There is a two-fold purpose for the muffler in a mechanical refrigeration system—to filter from the compressor discharge line those pulsations and noises introduced by the compression process and to serve as an accumulator for the compressor so as not to backload it. A rational design method based upon acoustical theory will yield a muffler which accomplishes both objectives. The method described herein is one which has been successfully used in the design of aircraft engine mufflers.[1]

A. F. MARTZ, JR. J. L. MARTIN W. R. DANIELSON

Since the muffler was designed by an application of acoustical theory it should be evaluated by acoustical methods to determine how well the theoretical design can be relied upon in practice. A component test of this type was therefore made. The test method utilizes a standing wave apparatus, loudspeaker, microphones, and the usual sound level measuring equipment.

Muffler Design – A muffler configuration consisting of two expansion chambers connected by an internal tube was chosen because it would give high attenuation at the desired frequencies and could be incorporated into the rearhead of our high side rotary compressor. Schematically, the muffler is as shown in Fig. 1. A qualitative explanation of its function can be made in the following manner.

A sound wave entering from the left will be partially reflected at the discontinuity at A. Of the sound energy which enters the first expansion chamber, some will form standing waves in it by reflection at the discontinuities at B and C and a portion will be transmitted through the connecting tube into the second expansion chamber. Standing waves will also exist in this chamber, and because reflections will occur at C and D, only a fraction of the sound energy in the second chamber will be transmitted into the exit tube.

The performance which can be expected of the muffler can be determined by the application of the transmission line equations developed in plane wave acoustical theory.[1,2]

The pressure existing in a plane wave distance x from the origin of the wave is

$$p = I e^{j \frac{\omega}{c}(x - ct)} + R e^{-j \frac{\omega}{c}(x + ct)} \quad (1)$$

Where I is the maximum pressure of the incident wave and R is the maximum pressure of the reflected wave, ω is $2\pi f$ and c is the velocity of sound. In Fig. 1 the origin of x is at A, positive x to the right. The particle velocity is

$$u = \frac{1}{j\omega\rho}\frac{\delta p}{\delta x},$$ ρ being the average density of the gas.

$$u = \frac{1}{\rho c}\left[I e^{j \frac{\omega}{c}(x - ct)} - R e^{-j \frac{\omega}{c}(x + ct)} \right] \quad (2)$$

The ratio of I_1 to I_{10} may be obtained by satisfying the boundary conditions at each point of discontinuity in the system by repeated application of equations (1) and (2). At points A, B, D, E, the conditions to be satisfied are that the total pressure and volume flow are each continuous at a surface.

thus, at A: $I_1 + R_1 = I_2 + R_2$ (3)

$$\frac{A_1}{\rho c}(I_1 - R_1) = \frac{A_2}{\rho c}(I_2 - R_2)$$

$$(I_1 - R_1) = m(I_2 - R_2) \quad (4)$$

where $m = \frac{A_2}{A_1}$

At B: $I_3 + R_3 = I_4 + R_4 = I_5 + R_5$ (5)

$$m(I_3 - R_3) = (I_5 - R_5) + (m - 1)(I_4 - R_4) \quad (6)$$

At D: $I_6 + R_6 = I_7 + R_7 = I_8 + R_8$ (7)

$$m(I_7 - R_7) = (m - 1)(I_8 - R_8) + (I_6 - R_6) \quad (8)$$

At E, assuming no reflected wave in the exit tube:

$$I_9 + R_9 = I_{10} \quad (9)$$

$$m(I_9 - R_9) = I_{10} \quad (10)$$

The boundary condition to be satisfied at C is that the particle velocity normal to the wall is zero.

[1] D. D. Davis, Jr., George M. Stokes, Dewey Moore, and George L. Stevens, Jr., "Theoretical and Experimental Investigation of Mufflers with Comments on Engine—Exhaust Muffler Design," N.A.C.A. Report 1192, (1954).

A. F. Martz, Jr., J. L. Martin and W. R. Danielson are with the Research Laboratories, Whirlpool Corporation. This paper was presented at the ASHRAE annual meeting, Lake Placid, N. Y., June 22-24, 1959.

[2] P. M. Morse, "Vibration and Sound", Chapter VI, McGraw-Hill, 1948.

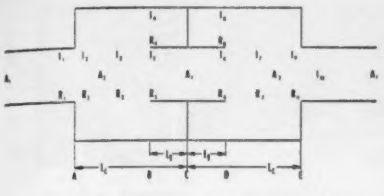


Fig. 1 Schematic diagram of sound distribution in muffler consisting of two expansion chambers connected by an internal tube

$$\text{Then } u = \frac{1}{\rho c}\left[I_4 e^{j\frac{\omega}{c}l^t} - R_4 e^{-j\frac{\omega}{c}l^t} \right] = 0$$

$$R_4 = I_4 e^{j2\frac{\omega}{c}l^t} \qquad (11)$$

$$\text{Similarly, } R_3 = I_3 e^{-j2\frac{\omega}{c}l^t} \qquad (12)$$

By using (1), I_3 and R_3 are expressed in terms of I_2 and R_2, at $x = l_c - l_t$. At B,

$$p = I_2 e^{j\frac{\omega}{c}(l_c - l_t)} + R_2 e^{-j\frac{\omega}{c}(l_c - l_t)} = I_3 + R_3 \qquad (13)$$

Similarly at D,

$$p = I_5 e^{j2\frac{\omega}{c}l_t} + R_5 e^{-j2\frac{\omega}{c}l_t} = I_6 + R_6 \qquad (14)$$

And at E,

$$p = I_7 e^{j\frac{\omega}{c}(l_c - l_t)} + R_7 e^{-j\frac{\omega}{c}(l_c - l_t)} = I_8 + R_8 \qquad (15)$$

By solving these 15 equations simultaneously, the ratio of the incident sound pressure to the exit sound pressure is found to be:

$$\frac{I_1}{I_{10}} = \cos 2\frac{\omega}{c}l_c - (m-1)\sin 2\frac{\omega}{c}l_c \tan\frac{\omega}{c}l_t + \frac{j}{2}\left[\left(m+\frac{1}{m}\right)\sin 2\frac{\omega}{c}l_c + (m-1)\tan\frac{\omega}{c}l_t\left[\left(m+\frac{1}{m}\right)\cos 2\frac{\omega}{c}l_c - \left(m-\frac{1}{m}\right)\right]\right] \qquad (16)$$

The transmission loss of an acoustical device is defined as $10 \log_{10}\frac{W_1}{W_2}$, where W_1 is the intensity incident upon the device, and W_2 is the intensity of the wave transmitted by it. Since the intensity of a plane wave is proportional to the square of its pressure, the transmission loss for the muffler becomes

$$\text{T.L} = 10\log_{10}\left|\frac{I_1}{I_{10}}\right|^2 \text{db} \qquad (17)$$

The squared magnitude of $\frac{I_1}{I_{10}}$, of course, is found as

$$\left|\frac{I_1}{I_{10}}\right|^2 = \left[\text{Real}\left(\frac{I_1}{I_{10}}\right)\right]^2 + \left[\text{Imaginary}\left(\frac{I_1}{I_{10}}\right)\right]^2 \qquad (18)$$

The transmission loss calculated by means of equations (16), (17) and (18) for a muffler to be operated in a refrigerant-oil system at 150 psia and 210 F is shown in Fig. 2. The dimensions of the muffler are such that

m, the area ratio, is 18. l_c = 1½ in. l_t = 1 in.
These were chosen to provide appreciable transmission loss at frequencies less than 1000 cps.

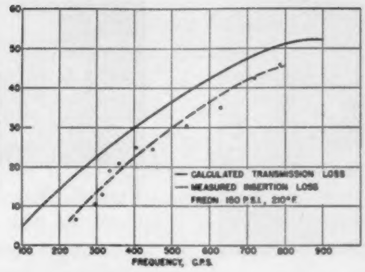


Fig. 2 Transmission loss for a muffler operating in a refrigerant-oil system

The rearhead muffler built to these dimensions is not a parallelepiped as is the prototype of Fig. 1, but rather the cavities are warped to fit the rearhead, as shown in Fig. 3.

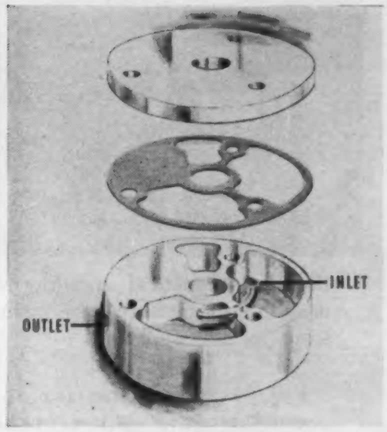


Fig. 3 Rearhead muffler with warped cavities

Experimental Methods—Apparatus: An acoustical standing wave apparatus was designed to measure the transmission loss and insertion loss of the muffler. Its general design is similar to several described elsewhere.[3] Its features are evident in Fig. 4 and in Fig. 5.

The output of a 6-in. loudspeaker is piped into the 1½-in. diam standing wave tube, and is transmitted from there into a conical tube, the apex of which is coupled to the muffler under test. In order to measure transmission loss, the sound pressure incident upon the muffler is required. This is measured by an encapsulated microphone to which is attached a small bore probe tube. The whole assembly is mounted on a carriage which slides along the bed to permit the measurement of standing wave maximum and minimum. Since the apparatus was designed to operate with the refrigerant at 150 psi and 210 F, the system is inclosed with a jacket for hot water.

The output end of the muffler is terminated in a section of steel tubing, 20 in. long, whose cross section is the same as that of standard refrigerator tubing. This discharges into a chamber which is 40 in. long and 1½ in. diam. It is partially filled with glass wool in order to minimize standing waves in the output system.

This latter is the most crucial feature of the apparatus. In order to measure transmission loss it is necessary that the muffler be terminated in a reflection-free tube in which the sound pressure can be measured.

Because this has not as yet been realized in a sealed system under pressure as described above, measurements to date have been made with the system open to atmospheric air pressure.

The termination then consists of the same small bore tubing as is used in the sealed system, and over a 2-ft length of it is snugly

[3] L. L. Beranek, "Acoustic Measurements", pp 326-329, Wiley, 1949.

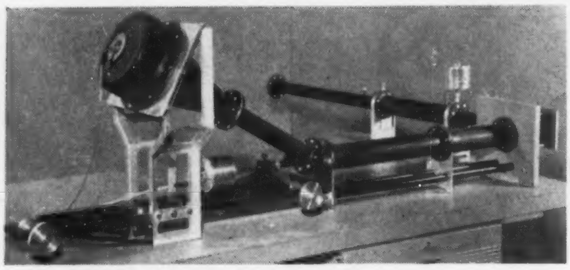


Fig. 4 Acoustical standing wave apparatus designed to measure transmission and insertion losses of the muffler

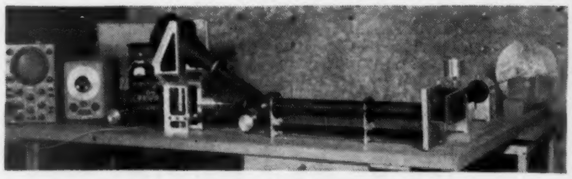


Fig. 6 Equipment modification to permit adjustment of the length of the tube so that pressure maximum and minimum can be read at the output of the muffler

Fig. 5 Schematic for the acoustical standing wave equipment shown in Fig. 4

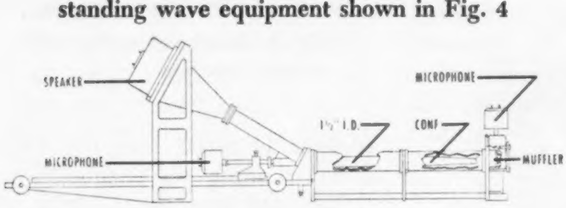
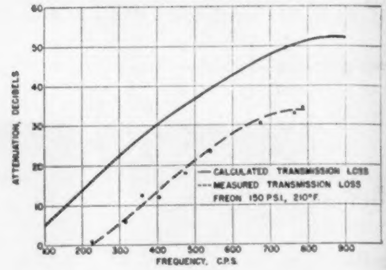


Fig. 7 Experimentally determined and calculated transmission losses compared



fitted a 2-ft length of tube which terminates in a 12-in. diam flange. The purpose here is to be able to adjust the length of the tube so that a pressure maximum and a minimum can be read at the output of the muffler. The flange helps by permitting more energy to be radiated by the tube so that the standing waves which do exist are minimized. The test equipment and experimental apparatus are shown in Fig. 6.

In the curves showing experimental data, the frequencies have been corrected to those which would be required to produce the same wavelength in the refrigerant at operating temperature and pressure as existed in air when the measurements were made.

Tests and Results—Measurement of muffler insertion loss provides performance data which are representative of the actual attenuation provided by the muffler in the system in which it is measured. Insertion loss is defined as the difference in sound pressure level, measured when the muffler is replaced by a tube of equal length, and when the muffler is inserted in the system, both measurements being made at a convenient point downstream from the muffler position. No elaborate mathematical formulation is required because the usual sound level meter indicates sound pressure level in decibels.

A microphone fitted with a short probe tube was used in making the insertion loss measurement. The open end of the microphone probe was inserted into the steel tube which served as the output termination for the muffler. The end of the probe was flush with the wall of the output tube. In order to reduce the acoustical loading which the microphone and probe might place upon the system, the probe has a bore of only 1/64-in.-diam and is less than 2 in. long.

Tests were made to determine to what extent the microphone probe affects the system. Similar probes were fitted into the muffler terminating tube at two additional stations. Measurements of sound pressure level were made both when the additional probes were inserted and when they were replaced with solid rods. The differences in sound pressure level were barely detectable on the meter used in this study.

The results of the insertion loss measurement are shown in Fig. 2, with the calculated transmission loss. The lowest frequency at which measurements were made is the lowest frequency at which the output tube propagates a wave outward. The highest frequency was dictated by the ambient noise level. It is seen that the measured insertion loss closely parallels the transmission loss calculated on the basis of no reflections in the output system.

The measured insertion loss, however, is a function of the ideal transmission loss and the reflections which exist in the output tube. The magnitude of the attenuation in a refrigerator installation, however, will depend upon the configuration of the tubing which connects the muffler to the succeeding component in the system.

Transmission loss data are especially meaningful if the measured transmission loss is $10 \log_{10} \left|\frac{I_1}{I_{10}}\right|^2$, under the condition that there is no reflected wave, for that is the basis upon which equation (18) is developed. Even though our muffler was terminated in a tube in which reflected waves did exist, it was possible to measure I_{10} as well as I_1. The transmission loss calculated therefrom, however, will not be the same as that predicted for the muffler, because the magnitude of I_{10} is affected by the presence of a reflected wave in the output tube.

Determinations of I_1 and I_{10} were made at discrete frequencies from measurements of the maximum and minimum sound pressure levels which existed in both the input tube and output tube. The tedious calculations outlined in the appendix were required to extract the magnitude of the incident waves, I, from the maxima and minima. The experimentally determined transmission loss is plotted in Fig. 7. Again, the calculated transmission loss is included for comparison.

CONCLUSION

A muffler designed for a refrigerator compressor by applying the acoustical theory succinctly represented by equations (16), (17) and (18) will attenuate in the range of frequencies for which those equations specify a substantial transmission loss. The magnitude of the transmission loss which will be physically realized depends not only upon the muffler design but also upon the existence or nonexistence of standing waves in the tube into which the muffler discharges.

The measured insertion loss, which is simply another figure of merit for muffler performance will also yield a curve which parallels the designed transmission loss.

In practice, it will always be exceedingly difficult to terminate a muffler with commonly used refrigeration tubing in such a way that no standing waves will exist in the terminating tube. The reason for this is that a small bore tube is a high pass acoustic filter. The smaller the bore, the higher the cutoff frequency at which the tube will begin to radiate efficiently. The frequencies of the waves which the muffler is called upon to attenuate effectively are well below the cut-off frequency of the small tubing, and the waves will therefore undergo multiple reflections in the tube.

APPENDIX

In a standing wave, the ratio of the magnitude of the reflected to the incident pressure is given as[4]

$$\left|\frac{R}{I}\right| = e^{-2\pi a}$$

The general expression for the magnitude of the pressure in a standing wave is

$$|P| = 2\, I\, e^{-\pi a}$$

$$\sqrt{\cosh^2(\pi\alpha) - \cosh^2(\pi\beta)}$$

Consequently,

$$|P\ max| = 2\, I\, e^{-\pi a} \cosh(\pi\alpha)$$

$$|P\ min| = 2\, I\, e^{-\pi a}$$

$$\sqrt{\cosh^2(\pi\alpha) - 1} = 2\, I\, e^{-\pi a} \sinh(\pi\alpha)$$

These are the quantities measured indirectly in the input and output tubes. $|I|^2$ is separated from |P max| and |P min| by taking the product:

$$|P\ max| \cdot |P\ min| = 4\, I^2 e^{-2\pi a} \cosh(\pi\alpha) \sinh(\pi\alpha)$$

$$I^2 = \frac{|P\ max| \cdot |P\ min|}{4\, e^{-2\pi a} \cosh(\pi\alpha) \sinh(\pi\alpha)} = \frac{|P\ max| \cdot |P\ min|}{2\, e^{-2\pi a} \sinh(2\pi\alpha)}$$

The hyperbolic angle is found from the relation

$$\frac{|P\ min|}{|P\ max|} = \tanh(\pi\alpha)$$

The maximum and minimum values of sound pressure level measured by the sound level meter are converted to |P max| and |P min| by applying the definition

$$S\ P\ L = 20 \log_{10} \frac{P}{Pref}$$

[4] P. M. Morse, loc. cit.

VORTEX TUBE PERFORMANCE (*Continued from page* 47)

The curves of Fig. 9B show that the refrigerating effect is a function of the length of the hot tube. Since the jacketed vortex tube showed no great improvement in efficiency over the split flow tube the investigation was not extended to include temperature distribution and heat transfer studies of the hot tube wall. Studies of this nature would be useful in applying the closed tube mode of vortex tube operation.

CONCLUSIONS

The tests reported here show that a vortex tube with the hot tube completely closed and with energy rejection by heat transfer through the hot tube wall to a surrounding cooling medium has about the same coefficient of performance as a conventional split flow tube operating at the same pressure ratio. The tests also revealed a whistling phenomenon which is accompanied by deleterious effects on the closed tube performance, but it is shown that maintenance of the hot tube length below a critical maximum will prevent these whistle effects.

This mode of operation of the vortex tube suggests applications where external coolants and regeneration might be employed to achieve cold air temperatures below those which are attained with the split flow tube. The closed tube system has the inherent advantage of rejecting heat at the relatively high hot tube temperature while not sacrificing any of the supply air to carry this heat away.

The absolute effectiveness of any of the various regeneration schemes which might be employed would depend upon the exact design employed, the temperature distribution and heat transfer along the hot tube wall, the proportions of the critical parts of the vortex tube itself, and the First Law of Thermodynamics.

Fig. 8 Vortex tube optimum proportions – 20 psig supply pressure

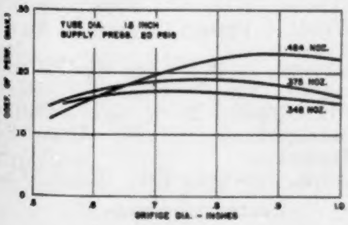


Fig. 9 Jacketed vortex tube performance (no whistle); effect of hot tube length on, A – coefficient of performance, B – refrigerating effect

FIG. 9A

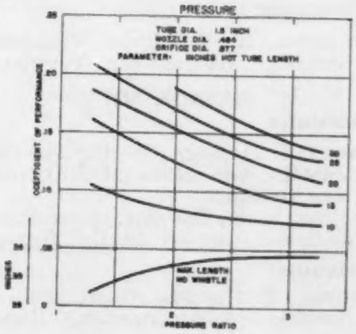
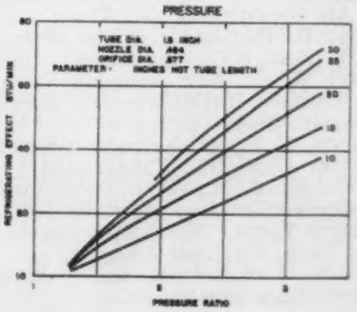


FIG. 9B



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(*Continued on page* 75)

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Adaptable for use with upflow, downflow or horizontal furnace installations using matching coils, the Miracool Air Conditioner is an air-cooled absorption refrigerated unit supplying chilled water to the cooling coil, and can be used for cooling alone with a fan-coil blower unit.

Payne Company, 855 Anaheim-Puente Rd., La Puente, Calif.

SUCTION-LINE HEAT EXCHANGER

Of all non-ferrous construction designed for 300 psig working pressure, this heat exchanger for commercial refrigeration systems features straight-through connections to eliminate oil trapping. Sub-cooling of the liquid prevents slugging of liquid to the compressor and improves expansion valve operation. Sized to match condensing units ranging from ¾ to 10 hp, these heat exchangers are dehydrated and sealed, then individually packaged in plastics bags.

Bohn Aluminum and Brass Corporation, Betz Div, Danville, Ill.

INTEGRATED AIR CLEANERS

Matching the style and dimensions of this manufacturer's air distributing units, Precipitron electronic air cleaners can be assembled in-line by bolting directly to them, becoming part of an integrated system for central plant air conditioning, heating and ventilating.

Designed for application at conventional coil face velocities between 350 and 600 fpm for capacities from 1950 to 28,800 cfm, these cleaners are only 25½ in. deep in the direction of the air flow, making the over-all system more compact. Collector plates can be washed either manually or automatically by a moving nozzle, collected dust being flushed and drained away without any need to enter the ductwork.

Westinghouse Electric Corporation, Sturtevant Div, Readville St., Hyde Park, Boston 36, Mass.

GAS CONVERSION BURNERS

Three sizes added to this line are AGA approved for 50,000 to 145,000, 50,000 to 210,000, and 100,000 to 310,000 Btu/hr input with natural, manufactured or mixed gas. With liquefied petroleum gas, the smallest and largest sizes are rated for 50,000 to 145,000 and 100,000 to 270,000 Btu/hr, respectively.

Henry Furnace Company, Medina, Ohio.

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Now available for pipe sizes from 4 to 8 in., Auto-Grip universal adjustable pipe hanger rings permit the use of this single type of hanger in most applications in place of a variety of other types of hanger rings. Consisting of a hinged metal band and a captive locking insert for attachment to a threaded hanger rod, is the universal design for large pipe sizes. Attachment involves squeezing the ring to release one end of the band from the insert, opening the band, slipping it over the pipe, and relocking the end of the band to the insert. The insert is self-locking by spring action reinforced by the weight of the pipe. To relieve expansion pressures on the hanger rod, the insert allows the ring to pivot through 2½ in. from vertical.

Automatic Sprinkler Corporation of America, Youngstown 1, Ohio.

MOISTURE-LIQUID INDICATOR

Featuring a fused sight glass intended to eliminate all danger of leakage by doing away with gaskets and springs, this moisture-liquid indicator is available for lines ¼-in. through 2⅛-in. OD. Sizes through ⅝-in. are available with male flare by male flare fittings, female swivel flare by male flare, and extended sweat connections. Sizes ⅞ through 2⅛-in. have extended sweat connections. All sizes are available without moisture indicators, if so desired.

Moisture-sensitive elements turn blue when the refrigerant is dry, pink when moisture is present. The units are designed so that leaching or discoloration is avoided.

Remco, Inc., Zelienople, Pa.

CONTROL SYSTEM FOR BOILER WATER

Designed to keep boiler water clear by eliminating sludge and suspended solids, this Automatic Side-Stream Boiler Water Control System is based on recirculating boiler water continuously through a side-stream filter and filter pre-coat. Available in standardized models for all types of steam boilers up to 1000 hp and in customized units for boilers up to 6000 hp, units combine side-stream filtration with chemical pretreatment, internal treatment, continuous minimum blowdown and feedwater preheating and degassing within the system.

Sparkler-Filtrion Corporation, North Chicago, Ill.

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Slim design permitting shallow depth mounting and convenient side access to terminals are among the advantages cited for this pair of cycling thermostat controls for air conditioning equipment. Designated the C21 (manual) and C22 (automatic) Series, the controls are designed to operate

(*Continued on page 83*)

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DALLAS COMMITTEE ON ARRANGEMENTS PREPARES FOR ASHRAE SEMIANNUAL MEETING

Well under way are plans for the ASHRAE Semiannual Meeting, Dallas, Tex., February 1-4. This second meeting of the Society is being built around an unusually significant technical program, the 2nd Southwest Heating and Air-Conditioning Exposition and social arrangements of exceptional variety and potential interest. A large attendance is anticipated. Here, as gathered for a recent session of the Committee on Arrangements, are (first row) J. F. Kistenmacher, H. G. Gregerson, G. A. Linskie, C. R. Gardner, Clarence Gilmore, Donald Hardin; (second row) Hugh Cunningham, S. E. Ammons, Elmer Gessell, J. P. Jordan, Thomas Anspacher, M. L. Brown, P. N. Vinther, Watson Keeney, R. E. Allison, C. H. Newby. Other committees are active, too.

ASHRAE REGION I TO MEET AT NIAGARA FALLS

Plans for a two-day Region I Meeting to be held in Niagara Falls, N. Y., October 9-10 are being speeded by the Western New York Chapter of ASHRAE.

Charles W. Stone and Carl R. Fagerstrom are Co-Chairmen of Arrangements. Other committee members include Frank Collins, Jr., Robert Jorgensen, Quentin P. Thompson, Paul D. Wyckoff and Robert L. Jameson.

As yet incomplete, the technical program will be held on Saturday morning. A special presentation of the ASHRAE Research Program will be made by Burgess Jennings, Director of the Research Laboratory.

Sightseeing trips to the Falls and to nearby power projects have been planned as well as special social events, beginning Thursday evening with a reception at the Treadway Inn, headquarters of the meeting.

BULLETINS

Miniature Temperature Controls. Nineteen different midget and miniature Thermoswitch Controls are described in 4-page Bulletin MC-182. Dimensions, temperature range, electrical ratings, and available modifications are given for each unit. Included for the first time is this line's newest hermetically sealed Miniature Control, Model 32411, which has contacts set to open on temperature rise.
Fenwal Inc., Ashland, Mass.

Liquid Polyvinyl Plastics. Heat-setting liquid polyvinyl plastics, known as Logosols, which may be used by hot or cold dipping; hollow or solid casting; and knife, roller or spray coating, are described in this 16-page booklet.
Bee Chemical Company, Logo Div, 12933 S. Stony Island Ave., Chicago 33, Ill.

Low Pressure Air Conditioners. Installation type drawings in 8-page Bulletin 9127 are used in conjunction with tabular references to provide complete outside dimensional data for all Inductor Air Conditioners for perimeter air conditioning of multiroom buildings. A simplified installation drawing of a typical constant volume low pressure cooling system is given to show how the units are used. Extensive tabular data present such information as heating coil capacities, gravity heating capacity, hot water and steam heating capacity factors, and water friction for various delivery volumes.
American Radiator and Standard Sanitary Corporation, Industrial Div, Detroit 32, Mich.

Chimney Construction. Standard recommendations for safe chimney construction, with drawings and ASTM specifications, are contained in 6-page Bulletin FL-259-27. Described are the advantages of clay flue lining in chimneys, cited as making homes and buildings fire safe and as being adaptable to any fuel.
Clay Flue Lining Institute, 161 Ash St., Akron 8, Ohio.

Zone Heat Control. Made in all standard pipe and tubing sizes, Zonvalve may be installed in any position on supply lines, radiators, convectors or baseboard. Designed to provide individual temperature control of each room in a building, this instrument is described in a 4-page bulletin.
Heat Timer Corporation, 657 Broadway, New York 12, N. Y.

Gas Vent Pipe and Fittings. Both round and oval type pipe and fittings in all standard sizes, adapter sections for transition from round to oval or the reverse and one size to another, birdproof roof caps, adjustable roof flashings and storm collars are included in the Metlvent line of double-wall, air insulated pipe and fittings for venting all gas-fired heating equipment and water heaters. Catalog No. 1, 20 pages.
Hart and Cooley Manufacturing Company, Holland, Mich.

Airborne Refrigeration Units. Detailed information on this company's new ½- and ¼-hp units designed for airborne applications is given in 4-page Bulletin TC-593. Available in both horizontal and vertical configurations, the units are manufactured to meet the requirements of Mil-E-5272A for military applications.
Task Corporation, 1009 E. Vermont Ave., Anaheim, Calif.

Activated Charcoal Filters. Replacing Form 76-3839 in Sweet's Catalog are 4-page Form 76-8042 and Flyer 76-8043, describing the benefits resulting from a system consisting of an electronic air cleaner and an activated charcoal filter.
Minneapolis-Honeywell Regulator Company, 2747 Fourth Ave. S., Minneapolis 8, Minn.

Refrigerant Condenser. Requiring no motors, fans, water or maintenance, this air-conditioning or refrigeration condenser is described in a 16-page manual. Included is a detailed explanation of Airvec's operating principle, specific advantages, installation

(Continued on page 102)

AIR FORCE HOLDS CONFERENCE ON REFRIGERATING AND AIR CONDITIONING

Men of the military and of industry got together at the sixth annual Air Force Refrigerating and Air Conditioning Conference at Wright-Patterson AFB, Dayton, Ohio, on July 13-16. Here grouped are: Rudy Berg, President of ARI; Brigadier General E. B. Cassidy, Director of Personnel and Support Operations for the Air Materiel Command, host to the conference; John H. Spence, International Educational Director, RSES; the Honorable John M. Ferry, Special Assistant for Installations, Office of the Secretary of the Air Force; Major General A. M. Minton, Director of Civil Engineering the U. S. Air Force; A. E. Manning, President of RSES; and Arthur J. Hess, President of ASHRAE. Some 300 conferees attended, nearly one-third of them from the air conditioning and allied industry.


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Wholesalers like it . . . contractors like it . . . journeymen like it!
It's the NEW standard of service and quality they're finding
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Stands to reason that the NEWEST multi-million dollar Scovill Tube
Mills, with every known aid to control of quality, WILL deliver
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We'll promise to make you a regular customer.
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MADE IN U.S.A. TO THE STANDARDS OF AMERICAN INDUSTRY
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is the new standard in
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Meetings ahead

September 2-4—Cryogenic Engineering Conference, University of California, Berkeley, Calif.

September 25-29—American Meat Institute, Palmer House, Chicago, Ill.

October 5-7—American Gas Association, Annual Convention, Chicago, Ill.

October 30-November 2 – Refrigeration Service Engineers Society, Annual Convention, Atlantic City, N. J.

November 1-2—Air-Conditioning and Refrigeration Wholesalers, Annual Meeting, Atlantic City, N. J.

November 2-5—11th Exposition of the Air-Conditioning and Refrigeration Industry, Atlantic City, N. J.

November 9-13 – National Electrical Manufacturers Association, Annual Meeting, Atlantic City, N. J.

November 9-13 – Institute of Boiler and Radiator Manufacturers, Semiannual Meeting, Absecon, N. J.

November 17-19 – Building Research Institute Conference, Washington, D. C.

December 3-5 – National Warm Air Heating and Air Conditioning Association, Annual Convention, St. Louis, Mo.

December 26-31 – American Association for the Advancement of Science, Annual Meeting, Chicago, Ill.

February 1-4 – American Society of Heating, Refrigerating and Air-Conditioning Engineers, Semiannual Meeting, Dallas, Texas.

February 1-4—2nd Southwest Heating and Air-Conditioning Exposition, Dallas, Texas.

March 6-10 – National Association of Frozen Food Packers, 19th Annual Convention-Exposition, Chicago, Ill.

May 1-4—Air-Conditioning and Refrigeration Institute, Annual Meeting, Hot Springs, Va.

June 13-15—American Society of Heating, Refrigerating and Air-Conditioning Engineers, 67th Annual Meeting, Vancouver, B. C.

People

Henry F. Dever, Vice President of Minneapolis-Honeywell Regulator Company in charge of its Industrial Products Group, has been awarded an honorary Doctor of Science degree by Bradford Durfee College of Technology in Fall River, Mass. Mr. Dever was cited for "unselfish service as an officer of various professional and humane societies." A graduate of Northwestern University, he is a trustee of Drexel Institute of Technology and director and former president of the Scientific Apparatus Makers Association.

E. M. Mittendorf, for the past nine years Director of Utilities and Lecturer in Mechanical Engineering at the University of Virginia, was recently elected President of the Virginia Society of Professional Engineers. An alumnus of Lehigh University, Mr. Mittendorff is past-President of the Illinois Chapter of former ASHAE, and member of the RAC on Steam and Hot Water Heating.

Lawrence H. Baker, former manager of the New York factory branch of Airtemp Div, Chrysler Corporation, has been named to the newly created post of Manager, field sales, applied machinery, and systems. He will supervise the firm's sales force for applied machinery, located in 12 district sales engineering offices throughout the country.

Edwin H. Young, on the department staff continuously for the past 12 years, has been promoted to Professor of Chemical and Metallurgical Engineering at the University of Michigan. For the past six years he has been director of the Wolverine Tube Finned Tube Heat Transfer Project in the University's Research Institute. Co-author with **Prof. L. E. Brownell** of the book "Process Equipment Design," published in June of this year, he is currently working with **Prof. D. L. Katz** on a manuscript for a book entitled "Heat Transfer Through Finned Tubes," and has co-authored fifteen technical papers on the same subject. A registered professional engineer in the state of Michigan, Prof. Young was recently promoted to the rank of Commander in the U. S. Naval Reserve.

W. Lloyd Algie will head the new heating and air conditioning div of Hamilton Plumbing and Heating Supplies, Ltd., and will concentrate on establishing dealers in the product lines of this division.

Richard J. Panlener, Director of Industrial Relations for Marquette University, has been nominated as vice president of the Engineers' Society of Milwaukee. If elected, Mr. Panlener, author of numerous articles and of Chapter 19 of the 1942 "ASRE Data Book," will be in line for the ESM presidency, this post traditionally being filled each year by the former vice president.

Roland A. Hazell, a member of the Johnstown Chapter, ASHRAE, has been appointed Manager, National Steel Boilers, Heating and Air Conditioning Div of National-U. S. Radiator Corporation. In his new position he will be responsible for the promotion and sale of the company's line of residential and commercial steel heating boilers. Affiliated with the firm since 1925, Mr. Hazell has served in a number of capacities in the accounting, manufacturing and sales departments, and was manager of the Canadian branch of the company prior to this appointment.

Ian Grad recently resigned as Chief Engineer with Fred S. Dubin Associates to open his own firm, Ian Grad Associates, Consulting Engineers, specializing in mechanical, electrical and industrial engineering. Mr. Grad, an alumnus of Rensselaer Polytechnic Institute, brings to the firm 11 years of experience with such companies as Voorhees, Walker, Smith and Smith; Kerby Saunders, Inc.; Eugene J. Brandt and Company; and Thermodyne Corporation.

James A. Rodgers, Jr., advances to the position of Manager of the Technical Sales Div of White-Rodgers Company. With the company since 1954, he will now be in charge of new product specification planning for future products approaching development stage. In addition, this division coordinates and distributes technical product information for use by the company field sales organization and acts in a product advisory capacity to top management.

Henry E. Cardenas will head the newly established Marine Department of Dunham-Bush, Inc., as Product Manager, making his headquarters in the company's New York office. Educated at the University of Havana, Mr. Cardenas has been engaged in marine refrigeration and air conditioning since 1936, for such firms as Carrier Corporation, Air-temp Div of Chrysler Corporation, and Stevens and Wood, Inc. For the past year he has served as project engineer with Hi-Press Air Conditioning of America.

Edwin G. Zanone, 47 years of age, died on May 7th. An engineer with Zanone Company, Inc., his former affiliations were Clayton and Lambert Manufacturing Company and Kentucky Metal Products Company.

F. E. Tapy has been appointed Manufacturer's Representative of the Young Radiator Company for the state of Nebraska and the western section of Iowa. He will represent their Heating, Cooling and Air Conditioning Div, handling air conditioning units, unit heaters, convectors, baseboard radiation, and heating and cooling coils.

Wesley R. Moore, past-President of the Northern Ohio Chapter of the former ASHAE, is on special assignment as Assistant to the President of Minneapolis-Honeywell Regulator Company at the firm's executive office in Minneapolis, leaving his former position as central regional manager.

Hugh B. Shepard has been appointed Maryland representative for Baltimore Aircoil, Inc., advancing from his position as Assistant Sales Manager.

Walter M. Hassenplug advances to the position of Executive Vice President of Acme Industries, Inc., and will concentrate his activities in the area of manufacturing, engineering, personnel and purchasing, in addition to contributing to overall company direction and management. Vice President and Director of Engineering since 1956, he is well known in the industry for the design of compressors, chillers and condensers, and has been responsible for the development of many Acme products.

C. A. Nolph has been named to the newly created position of Sales Manager of Military Equipment in the Machinery and Systems Div of Carrier Corporation. Formerly Sales Manager of the Syracuse district, he has been with the firm for 14 years.

W. H. Evans, President of Honeywell Controls, Ltd., Toronto, was recently elected President of the Canadian Manufacturers Association. Besides his new position, Mr. Evans is President of the Industrial Foundation of Canada.

Roger G. Anderson of F. W. Jenike Company has been appointed by Baltimore Aircoil Company to handle the evaporative condenser cooling line in southwest Ohio and nearby Kentucky and Indiana areas.

W. H. Sullivan, President and Treasurer of W. H. Sullivan Company, Inc., and a former mayor of Greensboro, N. C., died on June 28th at the age of 68, following a short illness. He was a director of the State College Foundation and Engineering Foundation; member of the Board of Trustees of the University of North Carolina, the North Carolina Society of Engineers and the North Carolina Building Code Council; and a former chairman of the State Board of Examiners of Plumbing and Heating Contractors.

Others are saying——

that . . . . . customarily, the transmittance of a structure is calculated from the conductivities and surface resistivities of its components. Cited as being the most suitable method for investigating these thermal properties is the guarded-box type method. Apparatus for this method comprises a heavily insulated impermeable box through which conditioned air is recirculated, a sample of the roof material to be tested forming a partition between the refrigerated upper and heated lower sections of the enclosure.

After setting the power consumption in the heater to a specific level and then allowing the roof to reach a steady temperature while maintaining a temperature of 32 F on the cold side of the sample, readings of the temperatures over the surfaces of the roof, together with those of the guard ring and hot-box air temperatures, were made. Heat flow through the roof over the area of the open face of the inner box was indicated by a wattmeter in the heater circuit. From this quantity, the mean temperatures of the roof surfaces and the air temperatures above and below them, the conductance and transmittance of the sample were found in the usual manner. *Journal of the Institution of Heating and Ventilating Engineers, June 1959, p 85. (British)*

that . . . . . . a four year study of the causes of break-downs in unit-type air conditioners revealed that failure of electrical components accounted for 63% of the cases, of the mechanical components 27%, and of the refrigerant piping the remaining 10%. Motor windings, bearings, controls, and refrigerant piping were the initial parts that failed in 87% of the cases. Detailed analysis showed that over 62% of the failures were preventable, had the units received attention while in operation. The preventable causes include failure to keep electrical components free of foreign materials and moisture, rewind or to replace motors having seriously deteriorated windings, tighten electrical connections

(*Continued on page* 99)

ASHRAE RESEARCH AND LABORATORY

(*Continued from page 61*)

nent staff, six to eight part-time subjects are used in the Environment Laboratory as test subjects.

Housed within the main laboratory is the Environment Laboratory. This facility, which was completed in 1958, makes it possible to control atmospheric conditions and, with the help of subjects, study human responses over a wide range of conditions. One of the studies being carried out in this connection is related to a complete re-evaluation of the comfort chart.

A solar calorimeter is also part of the research facility. In addition to making a number of fundamental solar measurements, it has also served for measuring the effectiveness of various fenestrations and of a number of shading and solar shielding devices.

Not all of the research work sponsored by the Society is carried out at the Laboratory. For many years it was an ASHAE policy to encourage research work in the Society's field of interest at universities and at other research institutions. Similarly, in ASRE, grants were frequently made for carrying out research in universities.

COOPERATIVE RESEARCH

At this time cooperative research projects are being carried out at the following institutions. In many cases, to aid the research, the Society has helped by means of a financial grant to the institution.

University of California
- Calculation of Cooling Loads from Pretabulated Impedances. (Project Completed)
- Design Feasibility Study of a Special Purpose Computer for Air-Conditioning Problems.
- Thermal Circuit Analysis of Flat Plate Solar Collectors. (Jointly with University of Minnesota)

Case Institute of Technology
- Model Studies in Air Distribution.
- Heat and Mass Transfer in Dehumidifying Processes. The latter project will investigate refrigerant heat transfer performance as related to moisture formation on coils.

Columbia University
- A Study of Vapor Flow Through Structures by Use of the Electric Analog.

University of Illinois
- Venting of Hot Water Heating Systems.
- Comfort Conditions for Industrial Workers.
- Frost Formation of Refrigeration Coils.

Kansas State College
- Determination of Heat Loss and Gains from Metallic and Non-Metallic Ducts Carrying High-Velocity Air.

University of Kentucky
- The influence of Bubbling and Rotational Turbulence on the Rate of Boiling from a Small Cylinder Immersed in a Liquid Refrigerant.

University of Minnesota
- Basic Character of Particulate Matter Present in Air and Factors Influencing Its Removal.
- A Study of the Effectiveness and Design of Solar Heat Collectors.
- Frost Heaving of Frozen Soils.

Northwestern University
- Studies of Noise and Noise Control in Liquid Piping Systems.

Pennsylvania State University
- Sterilization of Air by Solid Sorption Dehumidifiers.

University of Pittsburgh
- Lateral Exhaust Ventilation Studies.

Purdue University
- Adhesion Characteristics of Ice to Various Kinds of Surfaces.

University of Toledo
- The Sterilization of Air by Liquid Sorbents.

ASHRAE CHAPTER ORGANIZED IN NASHVILLE

At the organizational meeting of the Nashville Chapter, elections included: I. C. Thomasson, President; Roy L. King, Vice President; Theodore Moats, Secretary; James R. Potter, Treasurer; and Edward Kennedy, Robert Bibb and Farrell Hickerson, Board of Governors

PARTS AND PRODUCTS

(*Continued from page 75*)

window or unit air conditioners, compressors, strip heaters, and reverse cycle heat pumps under cross ambient conditions in a wide variety of applications. C21 has a 3 deg minimum differential and a 35 deg dial range, C22 a 3½ deg minimum differential and a 35 deg dial range. Electrical rating for both controls is 20 amp full load, 78 amp locked rotor at 115/230 volt ac; 20 amp at 250 volt ac non-inductive.
Ranco, Inc., 601 W. Fifth Ave., Columbus, Ohio.

TWO- AND THREE-HP UNITS

Incorporating standard four cylinder external mount compressors with the same basic design as the 4- and 5-hp compressors, the 2- and 3-hp low temperature commercial condensing units added to this line are offered for either single or three-phase, charged with Refrigerant-12, and available in either air or water-cooled models.

At −10 F the 2-hp air-cooled unit delivers 9700 and the 3-hp 14,000 Btu. Water-cooled units at −10 F deliver 11,190 and 15,280 Btu, respectively.
Tecumseh Products Company, Tecumseh, Mich.

THERMOCOUPLES

Multiple shielding for radiation protection plus induced velocity of gases in the low velocity probe are cited as reducing radiation error to negligible proportions for these high temperature thermocouples, permitting readings with an accuracy of five deg. Designed for use in gases moving at velocities in excess of 100 fps, the high velocity probe has a velocity recovery factor of approximately 90%.
United Sensor and Control Corporation, Box 127, Glastonbury, Conn.

VALVE-REGULATOR COMBINATION

Combining valve and pressure regulator into one unit, "Silent Knight" gas valves were designed to save installation time and space on all types of domestic heating plants. A vent device cited as allowing instant regulator response when the main valve opens eliminates time lag and possible flashbacks from the burner. When the main valve opens, the device's check valve equalizes pressure on the back of the diaphragm, allowing the regulator to reach full capacity immediately, additionally performing leak-limiting functions.

A variety of models and sizes are available, each being AGA listed for all types of gas. Combinations can be obtained with or without automatic recycling manual operator and plug-in pilot feature.
White-Rodgers Company, 1209 Cass Ave., St. Louis 6, Mo.

FIVE-TON CONDENSER

For homes and small commercial concerns, Model G&S 5 ton is rated at 60,000 Btu/hr at 95 F ambient, an increase of 6% over the capacity of former models. Featuring redesigned internal tubing, condensing coil and heat pump type compressor, the condenser is available in single and three-phase units.
Utility Appliance Corporation, Gaffers and Sattler Div, 8111 W. Beverly Blvd., Los Angeles, Calif.

MASS FLOWMETER

As a primary sensor, this instrument which measures liquid and gas flow directly in pounds, is expected to find application on automated systems since it emits a series of electrical impulses, each representing a given weight of fluid. This signal can be fed to auxiliary instrumentation, such as remote counters, printers, totalizers and control equipment.

A significant feature of the equipment is a silicon diode voltage source giving continuous standardization without using a dry cell, standard cell or standardization mechanism.
General Electric Company, Schenectady, N. Y.

MOTOR-COMPRESSORS DESIGNED FOR FLEXIBILITY

Powered by 3-phase 400 cps motors, these Hermetic Refrigerant Motor-Compressors for electronic cooling systems provide a flexible basic design, each compressor being tailored to the specific operating conditions. Refrigerant, displacement and motor size are based on the operating capacity and conditions required.

Light weight and small in size, the compressors may be operated in any position due to the oil-mist lubricating system. No oil sump as such is provided in the unit. The refrigerant and oil mixture is predetermined on the basis of the system in which it is used.
Great Lakes Manufacturing Corporation, 4223 Monticello Blvd., Cleveland 21, Ohio.

PRESSURE GAUGES

Made in all standard pressure ranges and in compound and vacuum types, the Master-test line of gauges is individually dead-weight tested and

Dow | INSULATION

STYROFOAM®

Key to permanently low operating costs

When Styrofoam* insulates low temperature space, the long term costs of operating refrigeration equipment tumble to a new low . . . and stay low, permanently! There's no loss of insulating efficiency with the passage of time, thanks to an unmatched combination of physical properties.

Here's a rigid plastic foam insulation with thousands of tiny, individual air cells in every cubic inch. This cellular structure provides an extremely low "K" factor plus high resistance to the passage of water and water vapor. With Styrofoam there's no water pickup . . . consequently its heat conductivity stays low. And when heat load stays at virtually the same low level over years of service, your equipment operating costs stay uniformly low, too!

And here's another important factor in low operating costs. Because Styrofoam won't freeze, swell or crack — won't permit ice formation, often the cause of buckled insulation—there's no need for periodic replacement and your equipment won't have to work overtime removing heat introduced during repair.

For more information, contact the Styrofoam distributor near you, or write THE DOW CHEMICAL COMPANY, Midland, Mich., Plastics Sales Dept. 2222JZ9.

*Dow's registered trademark for its expanded polystyrene

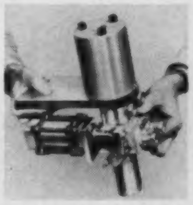
THE DOW CHEMICAL COMPANY • MIDLAND, MICHIGAN

guaranteed accurate within a quarter of one per cent, plus or minus, of the maximum dial reading over the entire range. Reading accuracy is obtained through a new type of dial, with an inner arc showing major marking and an outer mark showing the finer graduations, and by three reading methods: a twin-tip or gunsight pointer, a mirror scale and a dial cited as giving correct readings even when read at an angle.
Marsh Instrument Co., Skokie, Ill.

MIXING HEAD

Controlling two or three material streams with sharp cut-off for "on-off" operation is a rod-type valve, having Teflon seals and designed for continuous recirculation of chemical components when mixing is not taking place. This principle allows for pressure balance of the "Mix" and "Recirculate" cycles, producing proportioned components throughout the entire foaming cycle. Snap-action of this air-cylinder-actuated valve is cited as insuring reproducibility of shots for accuracy of pours in filling cavities and molds.

Producing foams of the rigid, semi-rigid, and flexible types using formulations of polyesters, polyethers, or castor oils, with throughputs up to 50 lb per min, the Standard Model Mixing Head serves as valve, mixer and dispenser of these polyurethane foams.



Martin Sweets Company, Inc., 114 S. 1st St., Louisville 2, Ky.

GLASS DOOR REFRIGERATOR

Designed to provide additional display area when used in back bar or open kitchen installations, the Full-Vue Glass Door Reach-In features a welded, thin frame and multiple pane, non-fogging glass units. Glass doors are available on all model reach-in refrigerators from 11 to 90 cu ft.
Jordon Commercial Refrigerator Company, 2200 Kennedy St., Philadelphia 37, Pa.

OUTDOOR COOLING TOWER

Reduction in floor area, weight and overall space requirements characterizes Model AST Econ-O-Mizer Cooling Tower, cited as resulting from its plastics deck, which consists of a series of polystyrene drip trays fastened into units to be stacked in the housing. Trays are staggered so that the water passes slowly downward from one to the next in a specific pattern. Control of drip pattern and air flow, not possible in the conventional outdoor tower, assures maximum contact between air and water with resultant high capacity and small size.

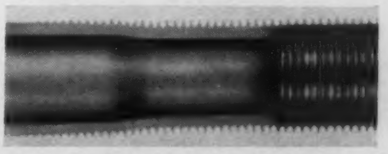
Larger sizes have dual cooling chambers with two incoming water distributing pans, dual fans and motors, a single sump and a full height dividing wall between the two sections, and can be operated on one cell to provide flexibility of operation and close control of leaving water temperature under partial loads.
Acme Industries, Inc., 600 N. Mechanic St., Jackson, Mich.

POWER GAS BURNER

Available in three models, of 400,000, 700,000 and 1,000,000 Btu/hr input, respectively, this burner is designed for the conversion of commercial and industrial coal or oil furnaces and boilers to gas. Intermittent pilot, burning only when unit is operating, and adjustment of amount of primary and secondary air in one operation are featured.
Liberty Combustion Corporation. E. Molloy Rd., Industrial Park, P. O. Box 300, Syracuse, N. Y.

INTEGRAL FINNED TUBES

Improved heat transfer characteristics over previous finned tube is cited for an integral finned low carbon and alloy seamless steel tube added to this line. Specifically designed for use in shell and tube heat exchangers, this tube increases the shell side surface more than 2½ times without alteration of normal fabricating procedures in the manufacture of such equipment.

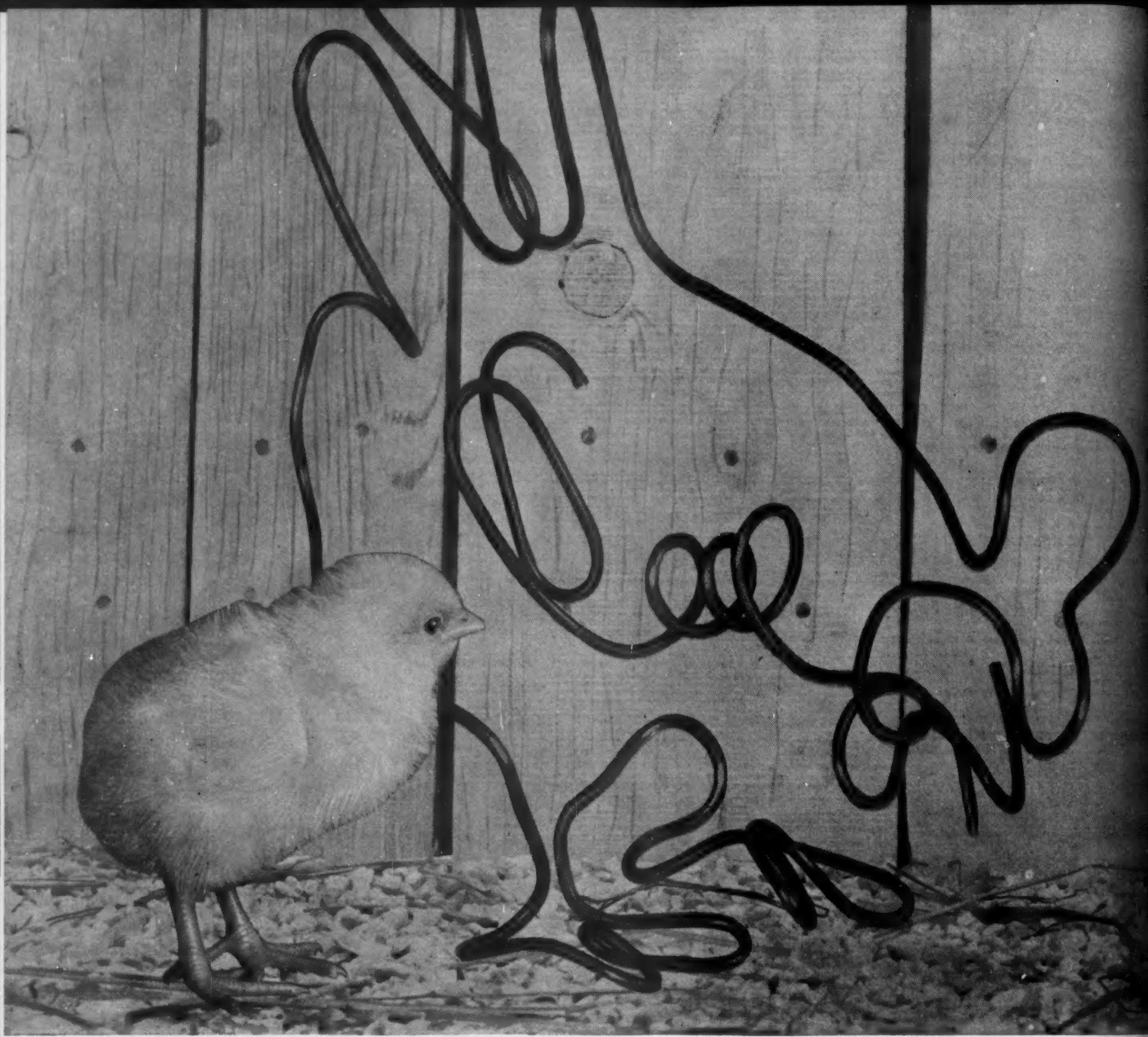


Furnished with plain ends for rolling into tube sheets with the OD of the plain end and the finned portion being the same, the tube is available in a wide range of alloys. Tube ODs from ½ to 1 in. can be furnished, with wall thickness of 0.035 in. and heavier.
Michigan Seamless Tube Company, South Lyon, Mich.

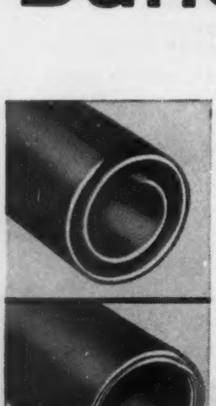
FUEL GAS VALVE

For on-off control and safety shut-off in gas-fired applications, these valves are cited as delivering up to three times greater flow for a given line size than globe-type valves, the inner valve in the open position being withdrawn from the main gas stream, giving straight-through flow unobstruct-

(Continued on page 90)



There's almost no limit to the things Bundy can mass-fabricate



Bundyweld is the original tubing double-walled from a single copper-plated *steel* strip, metallurgically bonded through 360° of wall contact for amazing strength, versatility.

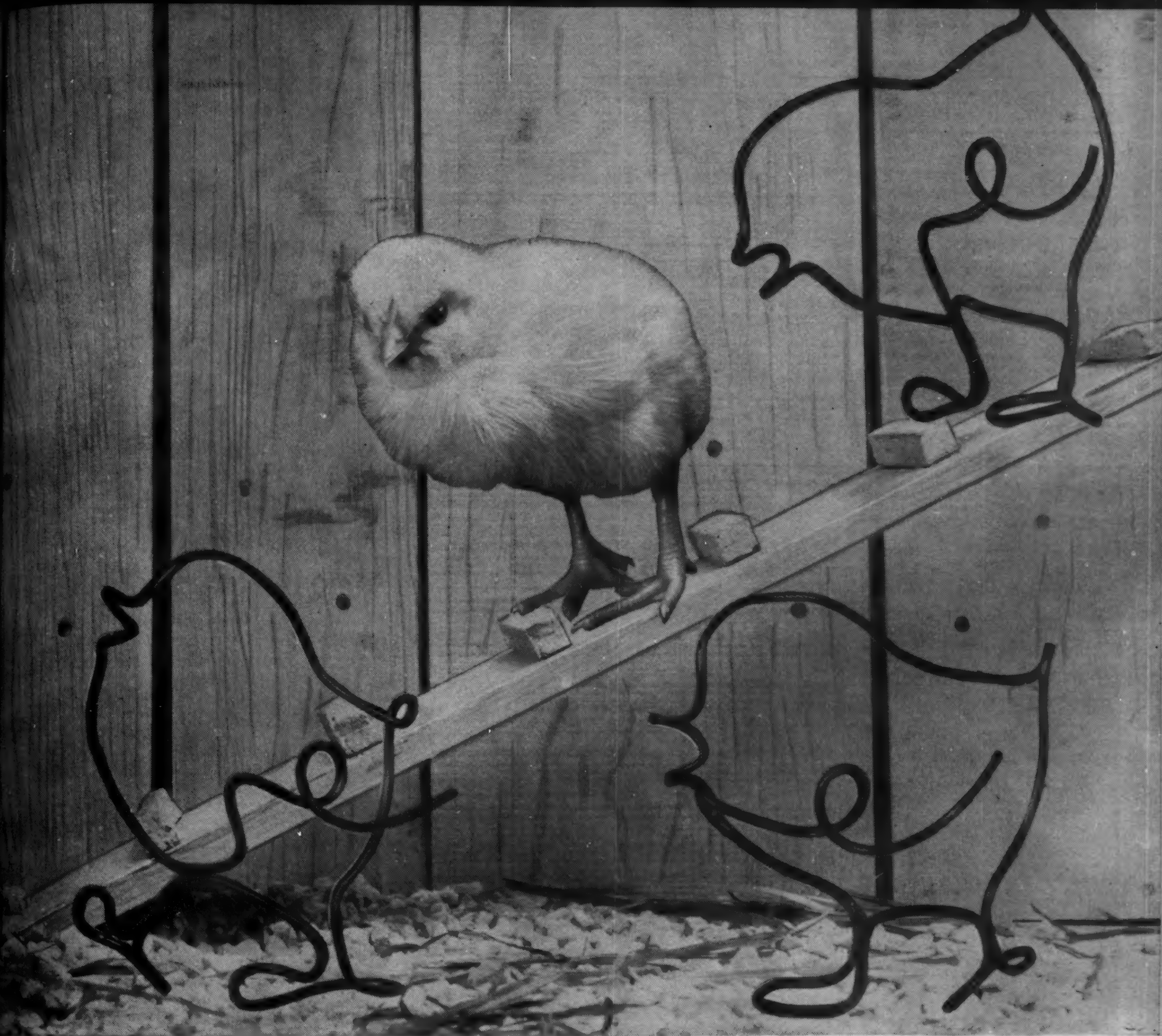
Bundyweld is lightweight, uniformly smooth, easily fabricated. It's remarkably resistant to vibration fatigue; has unusually high bursting strength. Sizes up to ⅝" O.D.

The old adage, "Don't count your chickens before they hatch," is a good one . . . but it rarely applies to Bundy. That's because, no matter how complex your tubing problem, you *can* count on Bundy for the perfect solution.

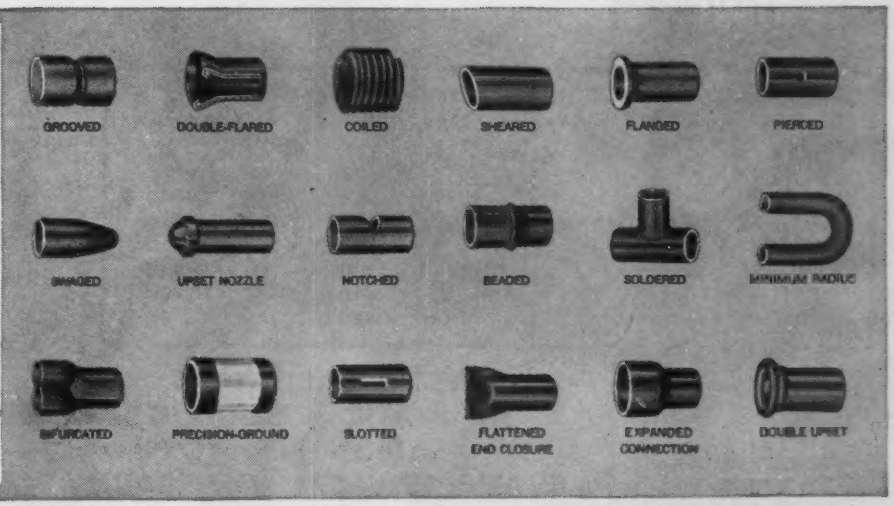
Bundy engineers and designers are backed by years of experience in the mass-fabrication of steel tubing. And they are available to you at any stage of product development for time- and money-saving suggestions. Their key: Bundyweld®!

Bundyweld steel tubing is double-walled, copper-brazed, leak-proof by test, and the safety standard of the refrigeration industry. Beveled edges provide smooth inside and outside seams. No inside flash to be removed.

So, when you want to talk tubing, talk to the leader—Bundy! Phone, write, or wire Bundy Tubing Company, Detroit 14, Michigan.



No matter what type of mass-fabrication you require, Bundyweld may be your answer. Shown here are just a few tubing operations designed and fabricated by Bundy—many for use in the refrigeration industry.



There's no substitute for the original

BUNDYWELD® TUBING

WORLD'S LARGEST PRODUCER OF SMALL-DIAMETER TUBING • AFFILIATED PLANTS IN AUSTRALIA, BRAZIL, ENGLAND, FRANCE, GERMANY, AND ITALY

BUNDY TUBING COMPANY • DETROIT 14, MICH. • WINCHESTER, KY. • HOMETOWN, PA.

(Continued from page 87)

ed by the valve mechanism. Constructed with two types of actuators, one manually and the other electrically reset, Hi-flo valves accommodate pipe sizes from 1 to 6 in., and can handle gas capacities up to 54,000 cu ft per hr at 1 in. pressure drop, based on 0.7 specific gravity of the gas.

Manually reset valves are actuated with a hand lever and held open magnetically. Power failure results in immediate and automatic spring closure of the valve.

Power-operated, the electrically reset valve is offered in either quick opening or adjustable slow opening types, the actuator being hermetically sealed in oil and requiring no adjustment or maintenance. Positive closing action is provided by dual relief valves which open to relieve hydraulic cylinder pressure. Actuators are optionally available with damper arm and auxiliary switches to interlock with indicator lights or other parts of the system.

General Controls, Inc., 801 Allen, Glendale, Calif.

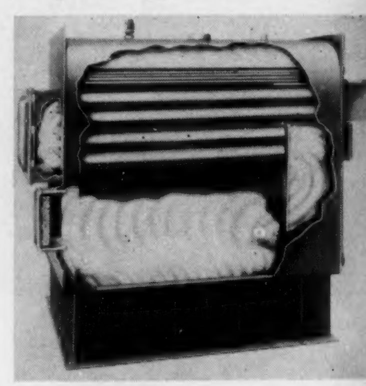
LOW-TEMPERATURE PIPE INSULATION

Especially suited for use at temperatures ranging from −300 to +220 F, this urethane foam pipe insulation is a closed-cell synthetic with excellent heat and chemical resistance, and is non-burning. Thermal conductivity tests have shown it to have a K factor of 0.14 at 70 F mean temperature. A closed cell content of 85% is said to give U-200 a high degree of resistance to water and vapor. Density of the material, which can be cut and applied with standard tools, is 2.3 lb per cu ft.

Union Asbestos and Rubber Company, Fibrous Products Div, 1111 W. Perry St., Bloomington, Ill.

THREE-PASS BOILER

Redesigned, the TP Series Three-Pass Boiler shown is cited as solving large structure heating requirements for steam and hot water and containing many new features. Flue gases pass through the fire box area, first along the crown sheet to the rear of boiler, then through the lower row of tubes to the front of boiler and back again through the upper row of tubes.



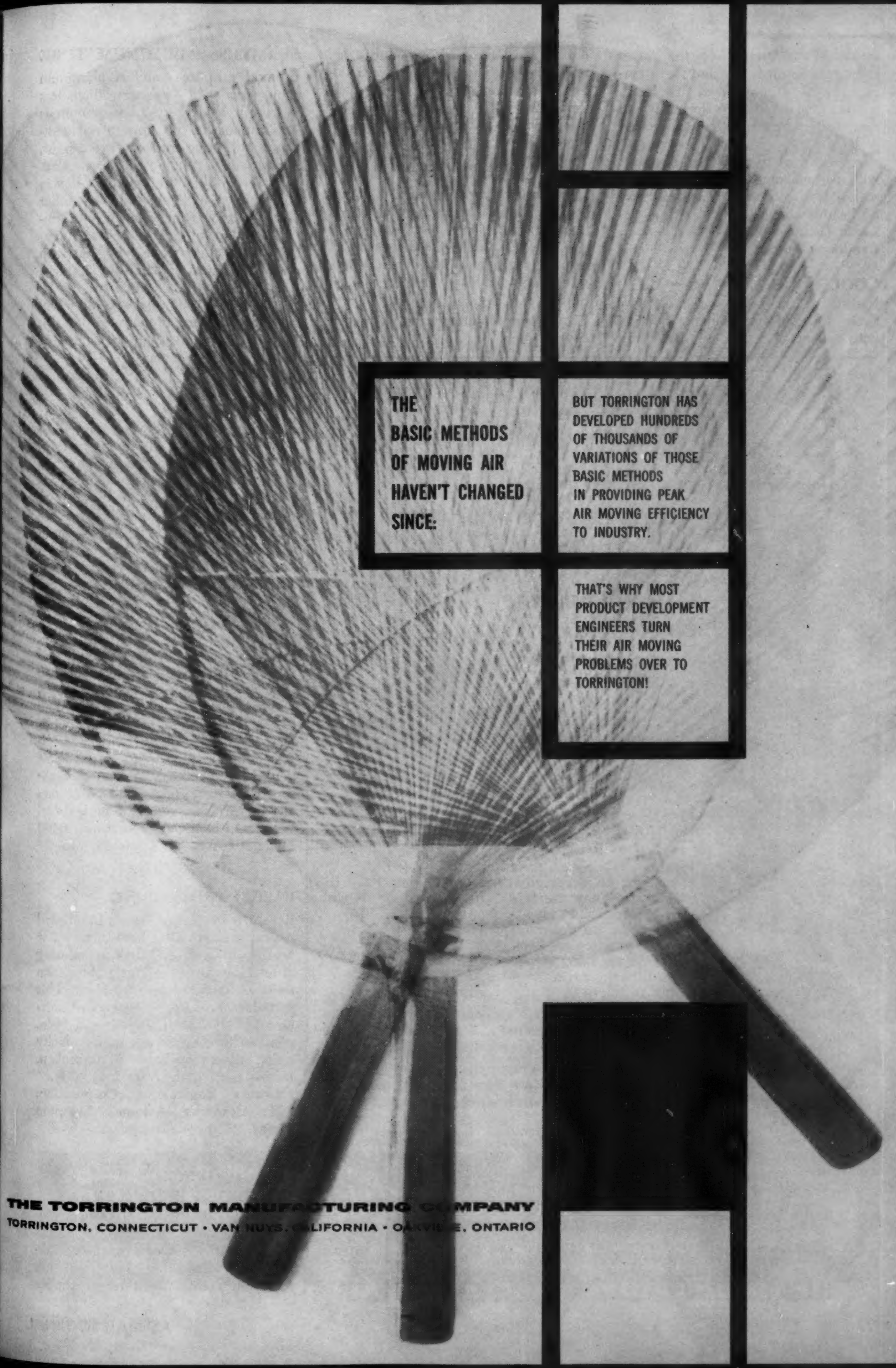
Available in 16 sizes, oil or gas-fired, the boiler is pressure-rated for steam at 15 psi and for water at 30 psi, and is available for 100 psi water working pressure. Steam capacities are rated from 3870 to 45,000 sq ft, water capacities from 6190 to 72,000 sq ft.

Portmar Boiler Company, Inc., 193 Seventh St., Brooklyn 15, N. Y.

TEMPERATURE REGULATOR FOR HEATING AND COOLING

Designated as Class M (direct acting) for heating service and Class MR (reverse acting) for cooling service, these temperature regulators for steam and water service are manufactured in ¾ and 1-in. body sizes in both cast iron and bronze with screwed ends.

Variations in temperature are sensed by a liquid-filled thermo-element. Volumetric expansion or contraction of the thermo-element fluid is translated


THE BASIC METHODS OF MOVING AIR HAVEN'T CHANGED SINCE:
BUT TORRINGTON HAS DEVELOPED HUNDREDS OF THOUSANDS OF VARIATIONS OF THOSE BASIC METHODS IN PROVIDING PEAK AIR MOVING EFFICIENCY TO INDUSTRY.
THAT'S WHY MOST PRODUCT DEVELOPMENT ENGINEERS TURN THEIR AIR MOVING PROBLEMS OVER TO TORRINGTON!
THE TORRINGTON MANUFACTURING COMPANY
TORRINGTON, CONNECTICUT · VAN NUYS, CALIFORNIA · OAKVILLE, ONTARIO

into uniform motion of the valve stem. Adjustment for any set temperature is accomplished by hand, turning an adjuusting sleeve which may be equipped with a calibrated dial.

A large variety of thermo-elements with various ranges, spans and bulb materials is available. Elements can all be interchanged.

Leslie Company, 107 Delafield Ave., Lyndhurst, N. Y.

COOLING COILS

Ratings of the Luxaire Counterflow Coils, when installed in conjunction with a 3 or 5-hp air cooled condensing unit, are 36,000 and 56,500 Btu/hr, respectively. These ratings were determined under standard testing conditions of 80 F dry bulb, 67 F wet bulb, and 95 F outdoor air temperature.

For installation beneath a counterflow forced air furnace, the units consist of a flat evaporator coil mounted horizontally and at a slight angle on a steel frame. Suspended beneath the coil are a series of zinc-coated drainage trays which capture the condensate water and carry it to a built-in drain pan.

C. A. Olsen Manufacturing Company, Elyria, Ohio.

SEAMLESS ALUMINUM TUBE

General purpose seamless aluminum tube, produced in many diameters and wall thicknesses, has numerous applications in plumbing, refrigeration and heating trades where a light, strong, easily-handled tube is needed. Made from 3003-0 aluminum alloy in soft temper, it flares easily, by either manual or mechanical means, and uncoils readily for cutting or straightening. Sizes range from ⅛-in. OD with a wall thickness of 0.025 in. having a bursting pressure of 1066 psi, to ¾-in. OD with wall thickness of 0.049 in. and a bursting pressure of 348 psi.

Chase Brass and Copper Company, Waterbury 20, Conn.

GEAR DRIVES

Enclosed gear drives are offered to meet the majority of application requirements for speed reduction units 125 hp and smaller, with output speeds ranging from 780 to 1.2 rpm at 1750 rpm input speed. Helical gears are heat-treated after cutting to obtain maximum hardness, while unit-type housings of corrosion-resistant cast iron have the output shaft endplate and the mounting feet or flange cast as integral parts for strength and rigidity.

Foot-mounted, flange-mounted and extended flange straight-line units are available as integral-type gearmotors, with the motor and speed reducer forming an integral assembly, as all-motor type gearmotors, with a standard motor coupled to the input shaft of the speed reducer, and as separate speed reducer units. The latter can also be furnished for right-angle drive.

Wagner Electric Corporation, 6400 Plymouth Ave., St. Louis 33, Mo.

BASEBOARD TUBING

Recently developed ½-in. baseboard tubing for zone control hot water heating systems is cited as offering industry-approved ratings greater than those of standard ¾-in. tubing. This manufacturer's line of baseboard units now includes both the ½- and ¾-in. nominal tube sizes plus high-capacity units; all are available in unbroken, factory-cut lengths from 2 to 20 ft.

Edwards Engineering Corporation, 101 Alexander Avenue, Pompton Plains, N. J.

NON-DUMPING RECORDER PEN

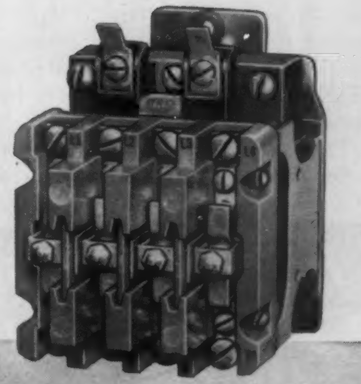
Developed for recorders used in mobile refrigeration, the Type B pen is cited as solving the problem of ink-dumping. Featuring a built-in ink reservoir, containing a larger supply

ESSEX ENGINEERED

This Complete RBM Control Family

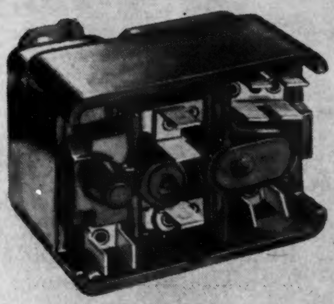
is specially engineered for the air conditioning industry

When RBM specially engineered its first air conditioning control, it quickly recognized the industry need for not just one . . . but for a *complete family*. So RBM has done the job. Now there is a single source for *all* magnetic air conditioning controls . . . each one meticulously engineered for its application. What's *your* requirement? See RBM.

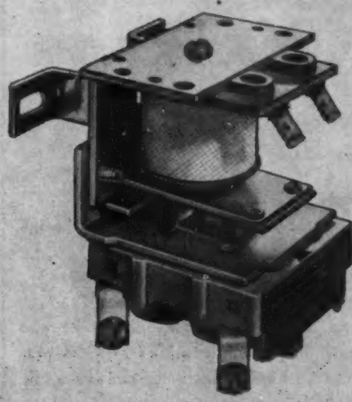


TYPE C—30, 40, 50 AMP. 2-3-4 pole 30 amp.—600 volts. 2-3-4 pole 40 amp.—230 volts. 2 pole 50 amp.—230 volts. Same mounting holes and coils for all ratings and pole forms.

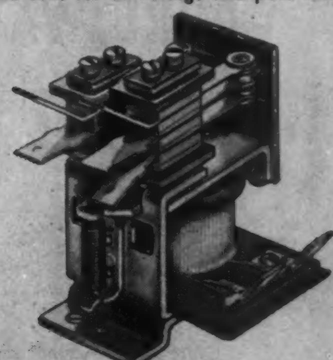
ALL PRICED TO MEET THE NEEDS OF VOLUME USERS



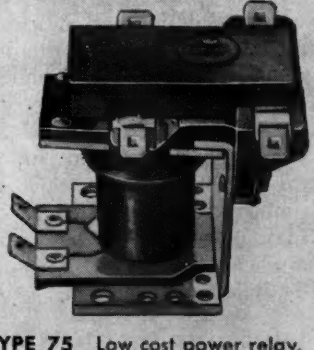
SERIES 128000 POTENTIAL STARTING RELAYS For starting single phase capacitor start compressors.



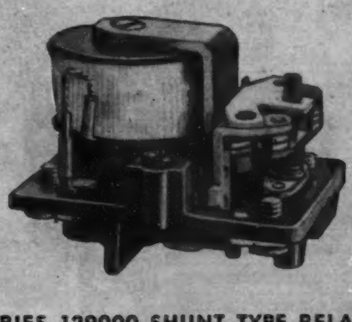
TYPE 80 CONTROLLER Specific design for nominal 3 HP or 3-ton single phase compressors.



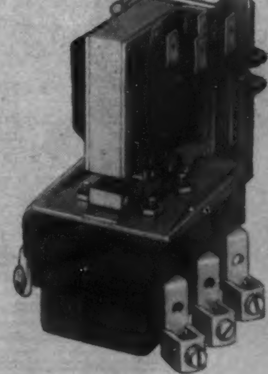
GENERAL PURPOSE RELAY 98000 Series AC or DC. Permits engineering short cuts lowering your "finished product" cost.



TYPE 75 Low cost power relay. Dependably handles up to 6000 W. at 240 V., resistive load per pole. Compressor rating 2 poles, 18 amp. running, 90 amp. locked rotor at 250 volts.



SERIES 129000 SHUNT TYPE RELAY—SPNO, SPNC or NO-NC For standard commercial voltages. Other coils available for special application. For heater, fan control, general circuit switching, etc.



TYPE S—30—40 AMP. Low cost. Small size. Exceed rigid requirements of industry's largest users.

Consult your local RBM Product Application Engineer or Write for Bulletins 1030A, C-8, 1010A, 1060 and C-10.

RBM Controls Division

ESSEX WIRE CORPORATION, LOGANSPORT, INDIANA

Factories Located at Peru, North Manchester and Logansport, Indiana

of ink than previously, and operating on the capillary tube principle, it will be furnished on shipments of all recorders for refrigeration transport use.
Partlow Corporation, 527 Campion Rd., New Hartford, N. Y.

HIGH-CAPACITY STARTER

Two contractors and starters for control of air conditioning compressor motors from 7½ to 20 hp, rated at 50 and 60 amp, 110/220 volt, or at 25 and 30 amp, 440/550 volt, have been added to this line.

Furnished with two or three poles, either form can be ordered with one auxiliary contact. Starters can be obtained with quick-trip overload relays for protection of hermetically sealed motors. Open or Nema Type 1 enclosures can be used. Starters are also available with conventional overload relays for use on air conditioning loads. The contactor can be used for ac non-inductive heating applications.
General Electric Company, Schenectady 5, N. Y.

MANUAL POSITIONING UNIT

Especially adapted for use with flow direction measuring probes which can be used to take traverses inside air ducts, turbine and compressor passages to determine air flow direction, velocity and temperature at each point, this unit can measure movement along one axis and rotation about the same axis. The movement can be measured to 0.01 in. with a vernier on a linear scale and 0.2 deg with a rotary vernier on a protractor. The unit can accommodate probes up to ½-in. diam with collets and pressure seal available for sizes from ⅛ to ½ in.
United Sensor and Control Corporation, Box 127, Glastonbury, Conn.

DIFFERENTIAL PRESSURE CONTROL

Designed for use in areas where explosive gases or vapors are present, Type J94K is a sensitive and explosion proof control, available in five models. Several system differentials are available between limits of 30 in. Hg and 40 psi, with switch differentials from 0.5 ± 1/10 Hg and up. This control is uncalibrated and pressure settings are made by removing the cover and adjusting the hexhead adjustment screw.

Switch actions include normally open, normally closed or double throw with no neutral position. Manual reset switches are also available when required. Switches are single pole and suitable for ambient temperatures up to 100 F and are rated 15 or 20 amp, 115/230 volt ac.
United Electric Controls Company, 79 School St., Watertown 72, Mass.

LOADED LIP SEAL ON PUMP

Developed to provide the greatest possible protection against leakage when used with all lubricating and fuel oils and most hydraulic oils, a special spring loaded single lip seal is featured on the LA series pump. Furnished in six different sizes with capacities to six gpm, for pressures up to 500 psi and at 3600 rpm, this pump can be used in a variety of hydraulic, fuel oil and lubricating applications.
Tuthill Pump Company, Chicago, Ill.

PRESSURE BLOWERS

Providing 8,000 to 64,000 cfm at pressures from ¾ to 2¼ psig, Series 2400 pressure blowers are equipped with airfoil blading to provide quieter operation. Rising pressure characteristic and inlet air spin control give stable air volume delivery for normal operating ranges and at reduced loads.
Westinghouse Electric Corporation, Sturtevant Div, 200 Readville St., Hyde Park, Boston 36, Mass.

(*Continued from page* 43)

Where systems provide essential make-up air, means should be provided to reduce the air supplied to the work zone without reducing the make-up volume to the general plant area. This can be done by deflecting the supply air up or down by directional outlets, or by the use of two-way dampers.

Commercial grilles and circular diffusers are most applicable to fully air conditioned spaces. Directional grilles and circular diffusers designed specifically for industrial applications, ball and socket, and various types of nozzle outlets are also available commercially. Custom designed outlets are limited in variety only by the ingenuity and imagination of the designer. The important thing is that they should be selected for the job requirements.

Directional grilles are best suited for general ventilation in open areas. Directional diffusers may be used for the same application, although they are more useful in aisleways or for spot cooling. Nozzles also are most applicable to aisle and spot cooling applications. Duct slot outlets may be used for nominal general ventilation or in areas where high entrainment and vigorous air movement are desired for close temperature or humidity control. Perforated sheet outlets or the equivalent in ceilings or wall plenums, or in ducts are a necessity in spaces of high air change where air motion must be at the minimum because of hood or process requirements.

CONCLUSION

It should always be kept in mind that the supply air systems in most industrial plants are utilities like power and steam. They are important to production. The equipment should be selected for reliability, good quality and low maintenance. Cost is most certainly a factor. But you get the kind of quality that you pay for. Cheap equipment is usually cheap in quality.

REFERENCES

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4. Small, Bartlett R.—Heat Relief in Industry, Iron and Steel Engineer, April 1952.
5. Small, B. R. — Summer-Winter Comfort Ventilation for Industry, ASHAE Journal Section, Heating, Piping and Air Conditioning, February 1957, p. 241.
6. Koestel, Alfred; Tuve, G. L.—Discharge of Air from a Long Slot, Transactions, ASHAE, Vol. 54, 1948, p. 87.
7. Koestel, Alfred; Hermann, Philip; Tuve G. L.—Air Streams from Perforated Panels, Transactions, ASHAE, Vol. 55, 1949, p. 283.
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This paper was one of four similar discussions by speakers at the ASHRAE Industrial Ventilation Conference at the annual meeting, Lake Placid, N. Y., June 22-24. The others are planned for publication in later issues of the ASHRAE JOURNAL.

Others are Saying—

(Continued from page 81)

and maintain electrical contact surfaces, maintain an adequate and clean supply of proper lubricating oil, determine the cause of and eliminate excessive vibration, properly adjust belt tension, and properly operate shut-off valves in the cooling water lines to condensers. *The Journal of Refrigeration, May/June 1959, p 65. (British)*

that . . . . . . in addition to the generally accepted good practices in pressure piping design and installation, refrigerant piping systems have certain operating characteristics that demand special consideration. The refrigerants themselves are often toxic and sometimes explosive; they undergo various physical changes in completion of their cycles; and they flow at lower than normal temperatures. The following ten rules are cited as being "musts" in the design and fabrication of these systems: select materials compatible with refrigerants; specify proper design temperatures and pressures; consider all applicable codes; do everything possible to avoid refrigerant leaks; mating flanges must mate; keep piping absolutely clean; use proper and sufficient supports, consider thermal contraction and associated stresses; consult qualified people for system design; apply sufficient insulation where required and seal completely against moisture penetration. *Heating, Piping and Air Conditioning, July 1959, p 106.*

that . . . . . . use of refrigerants to freeze a sub-surface area, permitting work to proceed without danger of subsidence, is a technique utilized in excavation of land with unstable subsoil. A system cited consisted of installing an intricate network of interconnected pipes in the area to be frozen, vertical units being fed by horizontal header pipes placed around the perimeter. Ten ton of refrigerated methanol solution was supplied to the system by two compressors and a heat exchanger unit. During a three month period the ground was frozen to a depth of 20 ft, well below frost level, and then for four weeks prior to excavation of the area and for eight weeks during the actual work, the refrigerant was cooled to —10 F. *Canadian Refrigeration and Air Conditioning, July 1959, p 21.*

that . . . . . . a small amount of hot water, passed through a well-designed and properly controlled piping system, affords a good way to minimize freeze damage to industrial ventilation systems handling freezing outdoor air. Water normally will not freeze if kept moving within the convector; its temperature can be varied easily and stably over a wide range to suit load conditions; and temperature stratification of air, due to nonuniform distribution of the heating medium within the convector, is eliminated with pumped water in the tubes. *Heating, Piping and Air Conditioning, July 1959, p 130.*

Applications

FOAMED URETHANE PLASTICS FOR FREEZING ROOM INSULATION

Gradual deterioration of insulation in the freezer tunnel of Lemon Products Div, Corona Plant, Sunkist Growers, made necessary the replacement of approximately 14,000 board ft of corkboard. Reinsulation with one of the closed-cell type of foam materials, in this case American Latex Products Corporation's Stafoam urethane, was decided upon, considering the extremes of temperature to be met by the material. A constant temperature of –40 F is maintained in the room, which is periodically defrosted, air at 130 F being circulated until room temperature reaches 70 to 80 F.

All damaged cork was removed from the walls, leaving a layer of cork 3 in. thick to provide a base for the foam. Removable plywood forms, loosely covered with slightly crimped aluminum sheet, were placed parallel with the wall and separated from it by 1¼ in. spacing blocks, and then temporarily shored. Pouring was accomplished by means of a portable, motor-driven mixing head supplied with resin, adduct and solvent by three 100 ft hoses. Discharge rate was 45 lb/min, foam rising to a maximum height of 18 in. in two min. A finishing pass was then made to bring the foam up to the top of the 36-in. form. After allowing 30 min for complete foam jellation, the forms were removed and raised higher on the wall for duplication of the foaming operation, this process being successively repeated until insulation of the room was completed.

Approximately 5260 lb of Stafoam formulation AA202 were used to foam 1200 cu ft, allowing for a weight loss factor and inevitable spillage for an average density of about 3.5 lb/cu ft. An estimated K factor of 0.14 achieved was made possible by the introduction of liquid refrigerant into the formula. During the exothermic reaction, the refrigerant vaporized, filling the cells of the material and increasing insulation efficiency.

REFRIGERATION CUSTOM DESIGNED TO COOL ROCKET PROPELLENT

Having a cooling capacity of 24 ton of refrigeration, this refrigeration plant, designed by Kohlenberger Engineering Corporation for Aerojet-General Corporation's Nitro-Compound plant near Sacramento, Calif., is intended for large volume process cooling of solid-propellant rocket fuel materials. Containing a complete 2-stage refrigeration system, using ammonia as the refrigerant, the unit employs a flooded shell-and-tube chiller with vapor dome, expanded polystyrene insulation, and high side float refrigerant control, and cools 75 gpm of methanol-water solution to –40 F.

(*Continued on page* 107)

BULLETINS

(Continued from page 78)

instructions, head pressure control valve chart, suggested combinations of sections from 2 to 200 ton, and diagrams of installations.
Edwards Engineering Corporation, 101 Alexander Avenue, Pompton Plains, N. J.

Dampers and Louvers. Among the items shown in this manufacturer's 4-page catalog are extruded aluminum, steel, galvanized or copper louvers, fire dampers, automatic dampers, ceiling and wall shutters, counterbalanced shutters, gravity or electric shutters and door louvers. Both oil-impregnated bearings and ball bearings are available in all styles.
Arrow Louver and Damper Corporation, 72 Berry St., Brooklyn 11, N. Y.

Cooling Coils and Condenser. Designed especially for installation beneath a counterflow forced air furnace, Luxaire Counterflow Coils, when installed in conjunction with a 3- or 5-hp Luxaire Air Cooled Condensing Unit, are rated at 36,000 and 56,500 Btu/hr, respectively. Rating and specifications, together with design and construction features, for both the coils and the condensers are given in 4-page Bulletin No. 295.
C. A. Olsen Manufacturing Company, Elyria, Ohio.

Linear Conversion Table. Suitable for many purposes in addition to its application to steel tubing, this table, TDC 110, is a handy reference for engineers, purchasing agents and others who have to convert inches and fractions of inches into decimal parts of a foot.
Babcock and Wilcox Company, Tubular Products Div, Beaver Falls, Pa.

Straight Line Thermostat. This line of room thermostats, for heating and cooling applications, is detailed in 4-page Bulletin GED-3585A. Included are performance characteristics, features, installation and wiring diagrams, equipment illustrations and current rating of popular controls.
General Electric Company, Schenectady 5, N. Y.

Mixing Head. Serving as valve, mixer and dispenser of polyurethane foams, the Standard Model Mixing Head described in this 6-page folder is capable of producing foams of the rigid, semi-rigid, and flexible types using formulations of polyesters, polyethers, or castor oils, with through-puts up to 50 lb per min.
Martin Sweets Company, Inc., 114 S. 1st St., Louisville 2, Ky.

Deep Groove Bearings. Open, equipped with shields or contact seals, and with or without snap ring, these deep-groove ball bearings in extra light, light, medium and heavy series are described in Bulletin 110.
Hoover Ball and Bearing Company, 5400 South State Rd., Ann Arbor, Mich.

Heat Exchanger. Cited as preventing coil frosting, oil foaming out of compressor and sudden drop in crankcase pressure, and permitting constant evaporator temperature and modulation of direct-expansion coil capacity by means of an external dewpoint controller, the Balance Loader is described in 4-page Bulletin BL-5. A heat exchanger, normally of the shell and finned tube type, it can be utilized in a refrigeration system to load a compressor artificially, so that its output can be modulated from 100% to zero while maintaining constant crankcase pressures.
M. Blazer and Son, Passaic, N. J.

Packaged Air Conditioners. Design and construction features of this line of packaged air conditioners are shown in 8-page Bulletin 8525, with capacities and physical data presented in tabular form covering both air and water-cooled designs.
American Radiator and Standard Sanitary Corporation, Industrial Div, Detroit 32, Mich.

Temperature-Humidity Chambers. Descriptive of this manufacturer's line of temperature and humidity chambers, ranging from a 2 cu ft portable unit to a 10 cu ft production testing model, is 4-page Folder No. 102. Included are a high-low temperature chamber with humidity control, a 2-chamber machine that can provide high and low temperature testing at the same time, and a special chilling chamber with arm holes permitting manual work with corrosive materials through gloves.
Harris Refrigeration Company, 308 River St., Cambridge 39, Mass.

Pneumatic Controls. Motors can be selected to meet the power requirements of each application in the MO903-MO904 Pneumatic Piston Damper Motor series described in 4-page Bulletin 76-4971. Designed for flexibility, the controls may be either

modulating or two-position. Special positive positioning is available for sensitive control. Length of piston travel can be adjusted easily and a Universal Mounting Bracket permits easy installation both internally and externally.
Minneapolis-Honeywell Regulator Company, 2747 Fourth Ave. S., Minneapolis 8, Minn.

Oil and Gas-Fired Furnaces. Flyers 158A for gas-fired and 159A for oil-fired describe the design and engineering features of Blue Ribbon winter air conditioners, including complete specification figures. Enumerated are features such as felt-cushioned drawer-type blower mounting, replaceable filters, return air knock-outs located on sides and rear of cabinet, and aluminum foil-faced insulation minimize cabinet heat loss.
Thatcher Furnace Company, Garwood, N. J.

Integrated Compressor Line. Descriptive of this manufacturer's line of hermetic and direct coupled drive units with 100% interchangeable components is 12-page Form 1100-B103.
Worthington Corp., Harrison, N. J.

Damper Control. Design, installation and operation of the Du-Air Damper Control for central heating-cooling combinations are detailed in this 12-page manual. Thermostatically controlled, the unit is a two-position damper control intended to provide two-volume air delivery, assuring the exact cfm for most desirable heating and cooling.
Morrison Products, Inc., 16816 Waterloo Rd., Cleveland 10, Ohio.

Expansion Joints. Intended as a brief digest of information on the nomenclature and selection of S-R Expansion Joints, and a guide to inquiries for specific applications, 6-page Bulletin EJC-591 contains general information on flanges, liners, covers, temperature ratings and other material.
Badger Manufacturing Company, 230 Bent St., Cambridge 41, Mass.

Gas-Fired Conversion Burner. Design features, AGA ratings and construction details are among the information given in Flyer No. 166 for this compact unit. Burner and pilot assembly are removable without disturbing the gas manifold, and the electrical system is the self-energizing type, making installation independent of an outside power source.
Henry Furnace Company, Medina, Ohio.

Low Temperature Testing Unit. Completely self-contained, ready for plugging into an electric outlet, this unit provides temperatures to −110 F or lower with either wet bath or dry storage. A liquid tight refrigerated area is available in capacities from 0.6 to 6.5 cu ft. The Low Temperature System can be used for chemical, oil, electronic, industrial, metallurgical, and other types of processing and testing. Flyer 4-23-59.
Remcor Products Company, 321 E. Grand Ave., Chicago 11, Ill.

Noise Control. Noise control applications for air conditioning systems, the aviation industry, and soundproof rooms for medical and research fields are among the items described in this 24-page booklet, "An Introduction to Noise Control."
Industrial Acoustics Company, 341 Jackson Ave., New York 54, N. Y.

Key Chart Booklet. Designed to save the serviceman's time in identifying and replacing refrigerator door gaskets, the 32-page Identi-Line Key Chart booklet lists almost 1000 different refrigerator models, showing the correct replacement gasket for each model. Form ID-500.
Jarrow Products, Inc., Chicago, Ill.

Individual-Room Air Conditioners. Three-way option for use is now offered the purchaser: with Spotaire LRC individual-room air conditioners: basic unit for concealed application, basic unit with plenum accessory, and cabinet model. Specifications and a table of nominal capacities are given in Flyer LRC-231 7-59.
Drayer-Hanson, Div of National-U. S. Radiator Corporation, 3301 Medford St., Los Angeles 63, Calif.

Air Movement. Included in a 12-page bulletin are complete specifications, dimensional data, velocity graphs and design features of the Wausau Air Mover. Illustrations show how air movement devises are tested and rated.
Greenheck Fan and Ventilator Corporation, Schofield, Wisc.

Radiant Heating Slab Construction. Designed to aid architects, engineers, heating and piping contractors, and others whose activities ally with accepted installation procedures for radiant heating systems, 8-page Bulletin No. 30-C-44 contains a digest of construction recommendations and sketches of various types of radiant heating slab construction. Each sketch

shows position of wrought iron pipe coils in the concrete slab, as well as relationship of coils and slab to structural features of on-grade and above-grade construction. Reviewed are floor surfacing, heating slab, radiant heating coils, insulation base or fill, waterproof membrane, and support brackets for radiant heating coils.
A. M. Byers Company, Box 1076, Pittsburgh 30, Pa.

Variable-Speed Pulleys. Technical data for five "MS" sheaves designed for ratings of 2, 3, 5, 10 and 15 hp are given in 12-page Bulletin No. 4101. Power is transmitted from the stationary flange through a removable sleeve cap, which is keyed to the moving flange by torsionally resilient rubber keys. A continuous rotational pumping action is cited as assuring a uniform, constantly renewed film of oil on the bearing surfaces.
T. B. Wood's Sons Company, Chambersburg, Pa.

Mercury Bulb Elements. Contained in Bulletin No. 851 is a description of different types of bulb elements and temperature ranges, information on the plungers and their interchangeability, designations and markings, various element plunger types and how to install the mercury bulb elements, and a chart on simple element specifications.
Partlow Corporation, 528 Campion Rd., New Hartford, N. Y.

Boiler Water Treatment. In addition to chemical and physical descriptions of di sodium phosphate, Technical Bulletin I-171 describes methods of external and internal application of the product to control scale formation in boilers.
Monsanto Chemical Company, Inorganic Chemicals Div, 800 N. Lindbergh Blvd., St. Louis 66, Mo.

Shock and Vibration Isolators. Selection of isolators for control of shock, vibration and noise is the subject of 4-page Bulletin 59-04. Given are definitions of "vibration" and "shock", reasons for use of an isolator, and step-by-step procedure in the determination of an isolator of the proper rating for the desired application.
Barry Controls, Inc., 700 Pleasant St., Watertown 72, Mass.

Tempering and Mixing Valve. Product features of the Tempo Type TMA Valve, designed for use on tankless heaters or storage tanks supplying domestic hot water, are outlined in Flyer No. 5-C-8. Noted are positive acting, fully enclosed thermostatic element, range from 110 to 180 F and top-mounted temperature adjustment dial.
A. W. Cash Valve Manufacturing Corporation, 666 E. Wabash Ave., Decatur, Ill.

Low Velocity Air Diffusers. Details give nominal sizes, cfm capacity ranges, special features and applications for each Multi-Vent diffuser described in 8-page Bulletin No. 649, which includes the recently developed combination air diffuser and flush-mounted ceiling fluorescent light fixture.
Pyle-National Company, Multi-Vent Div, 1334 N. Kostner Ave., Chicago 51, Ill.

Metal Packing. Designed specifically to acquaint users with pressure-temperature and other service requirements relative to the various kinds of metal packing currently available, 24-page Bulletin AD-166 contains comprehensive data for correct selection, application and installation of metal packing.

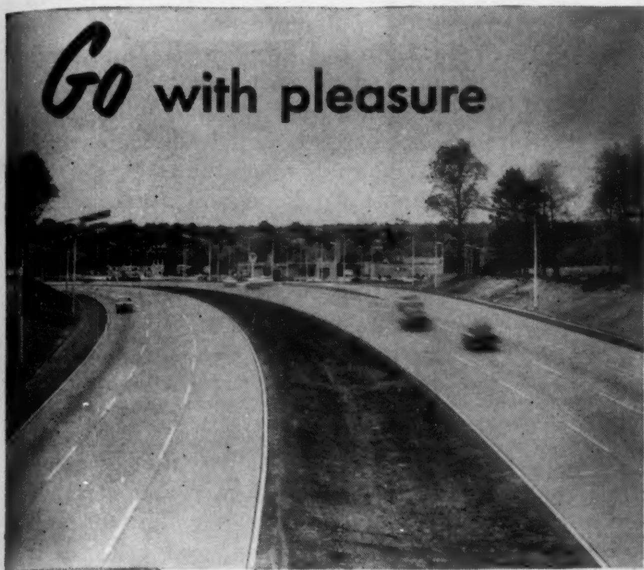
Subdivisions on free-floating metal packing, taking in detail the annular solid-cup type, high pressure packing and the split-case multi-groove type; metal rod packing rings; metal scraper rings; and metallic or non-floating packing and piston rings are included.
Garlock Packing Company, 438 Main St., Palmyra, N. Y.

Cooling Towers. Featuring a plastics horizontal deck cited as making possible weight and size reduction by as much as 50% and as eliminating problems of deterioration and fungus growth, the Econ-O-Mizer Cooling Towers are described in 4-page Catalog No. 362.
Acme Industries, Inc., 600 N. Mechanic St., Jackson, Mich.

Heat Exchanger. Specifically designed for commercial refrigeration and sized to match condensing units, the heat exchanger features all connections straight through, no oil trapping, low pressure drop, all non-ferrous construction, and 300 psig working pressure. Flyer 160.
Bohn Aluminum and Brass Corporation, Betz Div, Danville, Ill.

Fan and Limit Controls. Three basic types of controls are covered in Flyer GEA-6577A, which gives product features, dimensions, and complete rating information for 3AHL5, gas or oil, ¾-hp fan and limit controls for furnace applications.
General Electric Company, Schenectady 5, N. Y.

On the new *Connecticut Turnpike...*



ARCHITECT • CONSULTING ENGINEER • CONTRACTORS FOR HEATING, AIR CONDITIONING & REFRIGERATION
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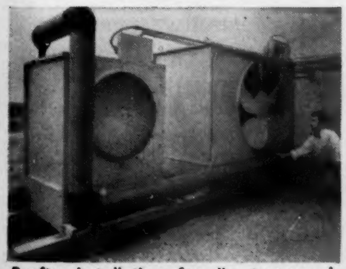
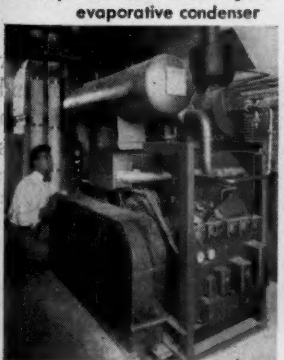
Comfort made possible by
COMPACT DUNHAM-BUSH EQUIPMENT

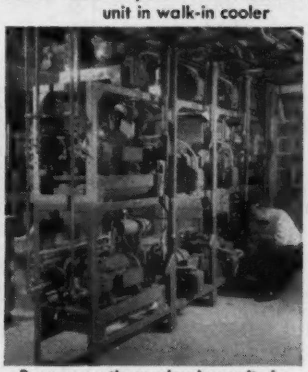


Rooftop installation of cooling tower and evaporative condenser

Low temp 'ED' electric defrost unit in walk-in cooler



'PC' 40 ton Heat-X package chiller for water chilling



Brunner-metic condensing units in rack assemblies

The matchless combination of engineered compact design and high performance efficiency—that's why Dunham-Bush was selected to serve the eight Savarin restaurants on the new Connecticut Thruway.

The single major problem at each of these eight locations was how to get maximum floor space to accommodate the many travelers, and yet have the kind of equipment necessary to insure complete customer comfort. A solution was sought . . . Dunham-Bush was selected.

Units of the following types are installed at each of the new eating places . . . for complete atmospheric comfort and proper food and drink conditioning: Packaged Water Chillers, Unit Coolers, Evaporative Condensers—all with patented Inner-Fin construction that permits compactness of design previously impossible; Air Handling units, Oil Separator Mufflers, and Rack Assembled Condensing units (for extra space-saving convenience).

Depend on Dunham-Bush, the single, compact organization that has the product depth, diversity, and experience to satisfy every demand for heating, air conditioning and refrigeration equipment.

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AIR CONDITIONING • REFRIGERATION • HEATING • HEAT TRANSFER

RESEARCH, CREATIVITY

(*Continued from page 62*)

These are but a few of the pertinent observations emanating from this conference which can be interpreted in relation to our own ASHRAE research program. Certainly, we wish to sponsor research which will have the most effective and telling long-range results on the direction and leadership which our society can provide to its related industries. From our research programs we hope will come results which will be broad in scope and suggest new facets of our industry as yet undreamed of and certainly currently unplanned. But to sponsor such research which will result in fundamental breakthrough similar to the development of the transistor in the electrical field, or nuclear energy in the power field, we must first recognize the inherent shortcomings of our organization setting.

We must recognize that creativity and technical breakthroughs are comparatively rare and certainly not predictable. Our society must be willing to spend some of its funds in free, unhampered research in broad areas of society interest and without detailed direction or continuous monitoring. The fruits of scientific creativity are not predictable in either time or nature, and the by-paths of an activity frequently lead to the most interesting and sometimes startling results. When research is channeled, directed and supervised by a group of minds it can result only in those facts toward which it has been channeled and directed and this is not fundamental research.

MAJOR OPPORTUNITIES

True breakthroughs come from the more sweeping wanderings of intelligent, imaginative, and unhampered minds, and the results are startling because they are not channeled toward those things which have been known and viewed before and which require only the additional grinding out of further facts. Industry must recognize that fundamental research often yields little in specific results for periods as long as five and sometimes ten years, and that this research is premised upon a confidence in imaginative people. Further, on average, it appears that only one in every five or six ideas probed is successful and develops further fuel for additional activity.

If the ASHRAE is to be involved in the sponsorship of fundamental research, this will demand long range research policies which will be difficult to maintain. This Society as with any other society is an entity made up of the sum total of its membership. For the greater part its actions and achievements are the integrated total of the gratis services of its membership. By its very nature a society is an amorphous thing with policies which shift in time and to some extent with the transient leadership of its officers. The face of the society tends to approximate the average characteristics, dreams, limitations and demands of its membership. It is this averaging characteristic which makes it so difficult to instigate and maintain

any true facet of a creative research program sponsored by this average entity called a society. As human societies throughout the world resist change and innovation, so our own technical society is not by its nature fundamentally constructed to sponsor the unusual, the unmonitored, and the unorganized.

Yet ASHRAE's research program in the past speaks fairly eloquently that it can on occasion sponsor fundamental activities which provide leadership for the industry. Historically, the records show that at the time when the industry was hampered by rule of thumb methods in the calculation of heating loads, often as much as 100 per cent in error, ASHVE sponsored a long range program on heat transmission through building research materials and introduced sound scientific procedures to these calculations. Our Society pioneered environmental research and developed the concepts of effective temperature, comfort zones and similar physiological - engineering studies. Our laboratories initially developed and first used heat meters. The records of this Society contain many other examples of activities which, while not necessarily technological breakthroughs, were certainly creative activities which have aided greatly the development of our associated industries.

Herein lies the challenge. We must be certain that in the future the measure of the success of the Society's program will not be those day to day activities and facts which are ground from organized and monitored activities. Sizable funds must be allocated to support creative people in an unhampered way and not under the continuous monitoring and directing of often quite good but "grouped" and thus "averaged" minds.

APPLICATIONS

(*Continued from page* 101)

First stage in the system is a heavy duty booster compressor; second stage is a Model KV-83 multi-cylinder compressor unit with 60 hp motor and automatic oil return discharge separator. The ammonia condenser has 7½-hp blowers and a 1½-hp water circulating pump.

All motor starters have "hand-off-auto" selector switches, and pump starters have a selector switch to put either pump in operation with the other pump on automatic standby. Thermostatic controls maintain "hands-off" operation in accordance with the methanol solution temperature at the chiller outlet, and a safety thermostat is used to prevent freeze-up damage. Other safety cutouts provide automatic protection against excessive high or low pressure operation, or oil pressure failure.

AIR CONDITIONING AN ADULT EDUCATION CENTER

Containing a lecture room, cafeteria, exhibit hall, and three floors of classrooms, the Adult Education Center of the University of Wisconsin presented a problem in the necessity for independent air conditioning of each of these areas.

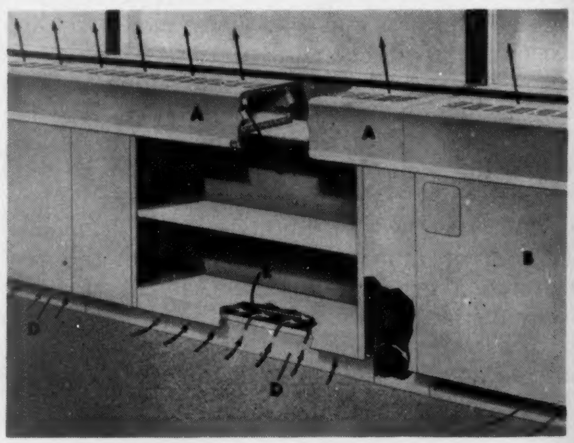
To fulfill this requirement, a central fan-coil system is used, individual room control being obtained by booster coils providing reheat. The central systems, one for each of the three classroom floors, are located in a penthouse over the central corridor of the third floor. All booster coils are located here to save on maintenance, and individual ducts are run to the various floors in furred spaces at the corridor walls. All air is delivered to the rooms through perforated acoustical tile ceiling.

Water for the central cooling coils is chilled by a 250-hp Hermetic CenTraVac, manufactured by Trane Company. Use of this large machine to cool only the administration section, which is often in use when the rest of the building is unoccupied, being considered impractical, a 10-hp Cold Generator and small chilled water pump were installed as the cooling source for this area. When the larger machine is in operation, the Cold Generator and small pump are automatically shut down.

By regulating steam heating coils, chilled water coils, and automatic outside return and exhaust dampers, the central systems are controlled. A humidistat is installed in the return air duct to maintain an average minimum relative humidity at all times. Individual room control is accomplished by modulating the automatic valves in the hot water branches of the Wall-Fin radiation and the booster coils.

PERIMETER AIR CONDITIONING

Pre-assembled ducts circulate conditioned air along exterior walls where most entrance of heat in summer and loss of heat in winter takes place. Designed by Trane Company, perimeter air conditioning is intended to circulate air in a room evenly, eliminating dead spots. Ducts extending air outlets along the full perimeter of the room also make it possible to reduce the number of air conditioning units, replacing several with one unit of larger capacity.



Illustrated is the air flow pattern of this Wall-Line air conditioner: (A) Fans push air through ducts. (B) Chilled or hot water is circulated, cooling or heating air as it passes over coils. (C) ½-in. insulation resists heat or cold air loss and acts as a sound deadener. (D) Circulated air returns through air intakes to be heated or cooled. (E) If a partition is placed over the spacer between units, air would recirculate to the air conditioner by intake under shelves.